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International survey of injury surveillance practices in competitive swimming

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ABSTRACT

Objective: The purpose of this study was to identify the injury surveillance practices being used in competitive swimming environments. It explored the nature of the data collected, the injury definitions used and the perceived effectiveness of injury surveillance. Finally, this study also examined barriers to injury surveillance.
Design: Online cross-sectional.
Participants: Twenty-two responders working in competitive swimming.
Outcome measures: Injury surveillance methods, data collected, perceived level of effectiveness and barriers associated with injury surveillance.
Results: Fifteen responders participated in injury surveillance, with 13 responders using a recognised definition for injury. Ten responders did not use any sports injury classification system. Ten responders found injury surveillance to be very effective at identifying injury trends, while previous injury history and training load data were perceived to be most influential in preventing injury. Limited time, funding and compliance were common obstacles, while poor staff communication and engagement were barriers to the effective implementation of injury surveillance.
Conclusions: The implementation of injury surveillance is related to the system objectives, competitive level of those under surveillance and the resources available. This implementation requires the balance of adhering to the principles outlined in prominent consensus statements and overcoming the barriers associated with implementing a system effectively.
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1. Introduction

The sport of swimming began its Olympic journey in 1896 (Hill et al., 2021) and was most recently featured at the Tokyo Olympic Games where a record total of thirty-seven events were contested. Despite recreational swimming being categorised as suitable for all ages and genders (Trinidad et al., 2021), competitive swimming at the elite level has a well-established risk of injury (Barry et al., 2021; Feijen et al., 2020; Hill et al., 2021; Trinidad et al., 2021; Wanivenhaus et al., 2012). A competitive swimming season typically involves large training demands that can be highly repetitive and is a year-round process. (Hill et al., 2015). Recently, an updated review of the epidemiology of swimming injuries described the incidence of injury (2.6–3.0 injuries per 1000 h of exposure) as "relatively low risk" compared with other upper limb sports (Trinidad et al., 2021). Overuse, non-contact injuries (Boltz et al., 2021) are most prevalent in swimming, with a significantly higher incidence of injury in training compared to competition (Soligard et al., 2017). Injuries in the sport are often non-time loss

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(Boltz et al., 2021) or time-loss with low absence rates from training (Prien et al., 2017). The shoulder is most frequently injured followed by the knee and lower back (Wanivenhaus et al., 2012). Injury burden, including the subsequent inconsistent training period and impacted performance, can have a significant influence on a competitive swimmer's career (Mitchell et al., 2021). Many swimmers train and compete with persistent health problems (Prien et al., 2017) and often use medication as a form of pain relief (Hibberd & Myers, 2013; Tessaro et al., 2017). Chronic pain in this population therefore can often lead to disability or retirement from the sport (Ristolainen et al., 2009; Tate et al., 2012; Trinidad et al., 2021).

Injury surveillance in sport provides critical information on the injury prevention practices needed to reduce the overall burden of injuries and, subsequently, improve performance (Tabben et al., 2020). Injury prevention practices are a key aspect of a swim programme and are underpinned by a clear understanding of the associated risk factors (Johnson et al., 2003) and high-quality epidemiological data (Ekegren et al., 2014). The development of a successful injury prevention programme is reliant on reliable, valid, consistent and population-representative injury surveillance data (Ekegren et al., 2014). Consistent and valid injury surveillance practices allow for the comparison of injury burden from season to season and can determine the effectiveness of an injury prevention intervention (Tabben et al., 2020). Gender, previous injury history, movement biomechanics, musculoskeletal deficits and training load have been identified as risk factors in a variety of swimming populations (youth, adult, club, varsity, elite, international, masters) through injury surveillance (Abgarov et al., 2012; Barry et al., 2021; Feijen et al., 2020; Harrington et al., 2014; Hill et al., 2015; Johnson et al., 2003; Tate et al., 2012; Trinidad et al., 2021; Wanivenhaus et al., 2012). However, it has been noted that the systematic collection of injury data is far from widespread outside of professional sport (Ekegren et al., 2016).

In 2016, a consensus statement on the methodology of injury and illness surveillance in aquatic sports was published by the Fédération Internationale de Natation (FINA) (Mountjoy et al., 2016). The objective of the consensus statement was to develop an injury and illness surveillance protocol that provided clear aquatic-specific definitions for the terminology and metrics used in aquatic injury and illness surveillance (Mountjoy et al., 2016). This was then followed by the International Olympic Committee (IOC) Consensus Statement, which sought to improve the consistency in data collection injury definitions, and research reporting (Bahr et al., 2020). Despite the publication of both consensus statements, substantial methodological and reporting gaps remain in recently published injury surveillance research (Trinidad et al., 2021). A similar finding was echoed by Barry et al. (2021), who highlighted methodological inconsistencies in training load monitoring in competitive swimming through a systematic review of the published literature. However, in a subsequent publication, the same authors discovered, through an international survey of training load monitoring practices in competitive swimming environments, the training load monitoring consensus guidelines (Bourdon et al., 2017; Soligard et al., 2016) were being followed at the practitioner level (Barry et al., 2022). The inconsistent findings between the systematic review and the survey investigation highlighted a research-practice gap within training load monitoring literature in competitive swimming. To this end, it is imperative to investigate the injury surveillance practices being implemented in practical competitive swimming environments and discover if a similar research-practice gap exists. This investigation can also provide insight which may refine future injury surveillance guidelines in competitive swimming environments. Therefore, this study aimed to identify the injury surveillance practices being used in competitive swimming environments, along with the nature of the data collected and the injury definitions being used. In addition, the perceived effectiveness of injury surveillance being able to highlight risk factors of injury, injury trends, informing injury prevention strategies and reduce the overall occurrence of injury was investigated. Finally, this study examined barriers to injury surveillance.

2. Methods

2.1. Experimental approach to the problem

A cross-sectional survey was designed to investigate the injury surveillance procedures and practices in competitive swimming. Competitive swimming was defined within the survey as, “competitive swimming, where the primary purpose of the sport is competitive performance, not participation”, while injury surveillance was defined as, “the method of habitually collecting data relating to the occurrence of an injury and the risk factors associated with it”. An open, thirty-seven-question survey was self-administered through an online platform (Qualtrics.com). The survey included open and closed questions, and used branch, display and skip logic functions to tailor the content depending on the specific responses. The reporting of the survey is in line with the Checklist for Reporting of Internet Surveys (CHERRIES) (Eysenbach, 2004). A copy of the survey is available online (Supplementary Information A), along with the CHERRIES checklist (Supplementary Information B).

2.2. Participants

The survey was initially circulated globally to practitioners within swimming National Governing Bodies (NGBs) from Ireland, Great Britain, Spain, Australia and New Zealand and subsequently to a number of coaching associations (International Swim Coaches Association, World Coaches Swimming Association, UK Strength and Conditioning Association) in order to increase participant recruitment. Practitioners were initially identified through NGB websites or professional contacts. In addition, coaches and practitioners from the NGBs were asked to circulate the survey to relevant contacts within their swimming community to generate a snowball sample. It was requested that the individual who had the primary responsibility for injury surveillance within their swim programme complete the survey. A total of twenty-two responses were collected. Ethical approval was granted by the University's Ethics Committee (2019_10_09_EHS). Participant information sheets (including a GDPR statement) were circulated with the questionnaire and each participant provided informed consent before participation in the research.

2.3. Procedures

The online survey was circulated primarily by email, but also through social media platforms (LinkedIn, Twitter) (Supplementary Information C) to maximise the survey's visibility. The aims, objectives and duration of the survey were included with each email, along with a participant information sheet. Data were collected from March to July 2020. Data gathered were identified using a code number, unnecessary personal details were not recorded or used in any part of this study and all data were stored using password-protection/encryption. Unique responses were identified using the IP address of the participant. IP addresses were cross-checked for duplications in Microsoft Excel during analysis and not used if found to be a replication. No duplications were found. The survey was designed to allow participants to review questions and change answers throughout the survey if needed. The survey consisted of five sections: (1) Informed Consent; (2) Demographics; (3) Injury Surveillance Practices; (4) Injury Surveillance Effectiveness; and (5) Barriers to Injury Surveillance. The survey was pilot tested, refined and redrafted through a three-stage process. Stage one involved discussing the optimal survey question flow to reduce respondent burden. It also involved improving question phrasing to ensure respondents interpreted the questions correctly and were not influenced by the order of the questions. Stage two included testing the survey with two academics with a background in injury surveillance research. Modifications of the survey in line with these consultations came in the form of improved technical terminology, further clarity on the phrasing of the questions and removal of irrelevant questions. The final stage involved a pilot test and trial analysis with two multi-sport high-performance support staff who regularly use injury surveillance in a practical setting. Pilot testing, outside of the academic sphere ensured the administration technique (email) was appropriate and that the terminology used transferred to the target population. Pilot testing, outside of the academic sphere ensured the administration technique (email) was appropriate and that the terminology used transferred to the target population. Post pilot testing, an individual debrief was conducted and highlighted areas of the survey that may have been problematic for the user (skipped questions, questions answered incorrectly or misunderstood). The individual debrief lead to the re-ording of questions and additional clarity of terms used such as “professional accreditation” and “questionnaires”. The addition of contextual examples and set definitions where also added to terms including “incidence”, “severity”, “injury/illness burden”.

2.4. Statistical analyses

Collated data were analysed using frequency analysis within Microsoft Excel. Absolute frequencies were predominantly used to report the data. Where data were qualitative, thematic analysis techniques from Braun et al. (2016) were employed. The thematic analysis employed a six-step process, including data familiarisation, coding, theme selection, refining themes, defining themes and finalising the report (Braun et al., 2016). Line by line coding was applied to the open-ended questions by one author (LB). Themes were then developed from these codes by two authors (LB, KM). Representative quotations were then extracted, agreed by both authors and presented for each theme.

3. Results

3.1. Demographics

A total of 22 responses were collected. A range of professionals (swim coach (n = 9), physiotherapist (n = 9), strength and conditioning (S&C) coach (n = 3), athlete health lead (n = 1)) responded to the survey as the primary staff member responsible for injury surveillance practices. Responders had either a Bachelor's degree (n = 8), Master's degree (n = 12) or PhD (n = 2), and many (n = 17) had a complementary discipline-specific qualification (e.g. UK Strength and Conditioning Association, Level two/three Swim Coaching Accreditation, CORU Registration). Responders often (n = 12) worked with swim squads containing multiple performance levels (international n = 17, national n = 12, club n = 10), with group sizes ranging from 5 to 350 athletes.

3.2. Injury surveillance practices

A total of 15 responders acknowledged using injury surveillance practices, with the remaining seven citing limited time (n = 4), lack of sufficient funding (n = 2) and/or a lack of compliance from athletes (n = 1) as being the key barriers that prevented them from employing injury surveillance practices. Responders highlighted the primary goals of injury surveillance within their programme were, “to keep a record for insurance purposes” (n = 7), “to analyse in relation to other training factors” (n = 5), “to inform appropriate athlete training prescription” (n = 4) and/or “to highlight trends in injury occurrence” (n = 2).

When asked about the detail of their injury surveillance practices, responders noted that either the FINA (n = 6) or IOC (n = 6) definition for injury was predominantly used, with one responder using the Australian Institute of Sport (AIS) definition (2014). One responder used a combination of both the IOC and FINA definitions and one relied on a custom definition which noted an injury had occurred if it related to any modification of swim training. The majority of responders (n = 14) noted that they sub-categorised injuries, with all responders gathering additional injury or athlete specific detail during the recording process. Table 1 illustrates the information gathered.

Primarily, injuries were recorded by a physiotherapist (n = 6), swim coach (n = 3), sports therapist (n = 2), S&C coach (n = 2), sports scientist (n = 1) or by the athlete (n = 1). In most cases (n = 12), injury diagnosis was confirmed by a doctor or physiotherapist before it was recorded and specific software (n = 6) or a spreadsheet (n = 5) was used to store the information. Where an injury classification system was used (n = 4), the Orchard Sports Injury Classification System (OSICS) was employed. However, a large portion of responders (n = 10) used no formal classification system (one responder was unsure of the system used). All but one responder highlighted recording additional training or athlete data in conjunction with their injury data (see Fig. 1).

Once data were collected, eight of the responders performed further analysis. Where further analysis was performed, injury prevalence (proportion of athletes affected by a specific condition at a defined period) (n = 8), injury incidence (number of new occurrences of an injury in relation to the number of athletes at risk during a given period) (n = 6), injury per training exposure (number of injuries recorded per training hours) (n = 5) and injuries related to primary swimming stroke/distance (n = 5) were most commonly used.

3.3. Injury Surveillance Effectiveness

Responders highlighted the effectiveness of their injury surveillance practices in key situations associated with a training environment. The most frequent response in each scenario is highlighted in Fig. 2 below:

Responders also ranked the three most influential data or metrics that they used for preventing injury. Previous injury history (n=7) and training load (n=5) were the two highest-ranked variables as seen in Fig. 3 below:

3.4. Barriers preventing injury surveillance

Seven responders stated that they did not employ any injury surveillance practices. The barriers that prevented them from employing injury surveillance practices were cited as “limited time” (n = 4) “lack of sufficient funding” (n = 2) and “lack of athlete compliance” (n = 1).

Out of the remaining 15 responders who did employ injury surveillance practices, 11 acknowledged having barriers associated with conducting an effective injury surveillance system. Five overall themes were identified, with three of them being similar to those who did not employ injury surveillance practices (a lack of funding, time and compliance). In addition to these, poor

Table 1
Sub Categorisation of injuries broken down by the number of responders.

Sub- Category	No. of Responders
Overuse injury: Refers to a condition caused without a single, identifiable event responsible for the injury.	12
Re-injury: Injury to the same location and of the same type as the index injury, where the index injury has completely healed.	11
New injury: Injury to a different location from the index injury.	8
Time loss injury: Injury that results in being unable to take a full part in future training or competition.	8
Traumatic injury: Refers to an injury caused by a single, clearly identifiable episode.	7
Medical attention injury: The swimmer needed an assessment of their medical condition by a qualified medical practitioner.	6
Exacerbation: Injury to the same location and of the same type as the index injury, where the index injury has not completely healed.	5
Index injury: The first recorded injury in a series of injuries constituting a recurrent condition.	3
Local injury: Injury to the same location but a different type from the index injury.	3
Non-Time loss injury: Injury that results in full participation but with health problems or reduced participation due to health problems.	3
Additional Details	**No. of Responders**
Date of injury	15
Body location of injury (e.g., Arm/shoulder)	15
Mechanism of injury (how the injury occurred)	12
Impact of injury (Duration (days) away from training/competition)	12
Injury type/diagnosis	11
Date of return to full participation	10
Type of session where the injury occurred	9
The severity of injury (mild, moderate, severe, Grade I, II, III etc.)	7
Injury "Aggravators & Easers" (including swim specific technical changes)	1
Sleep/stress/nutrition/hydration/general health/musculoskeletal history (fatigue, soreness, tension, pain etc) in the preceding weeks	1

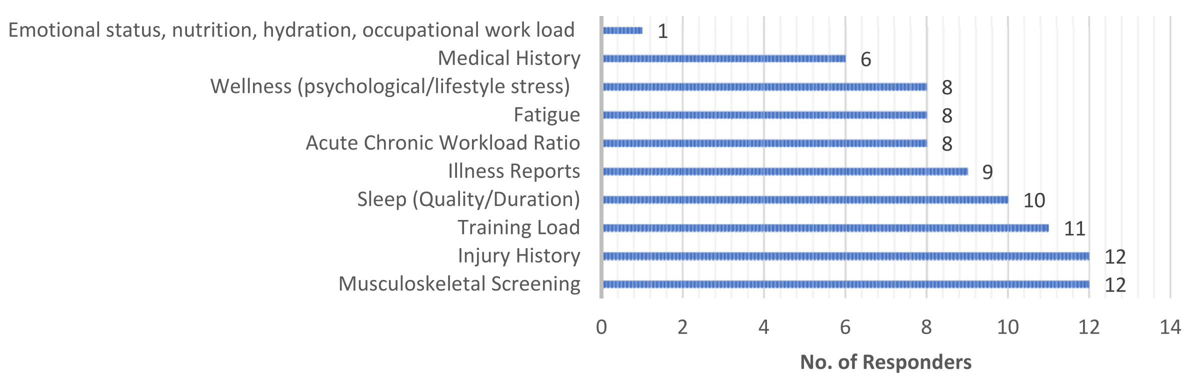

Fig. 1. Additional athlete data (collected in conjunction with injury data) broken down by the number of responders (n = 14).

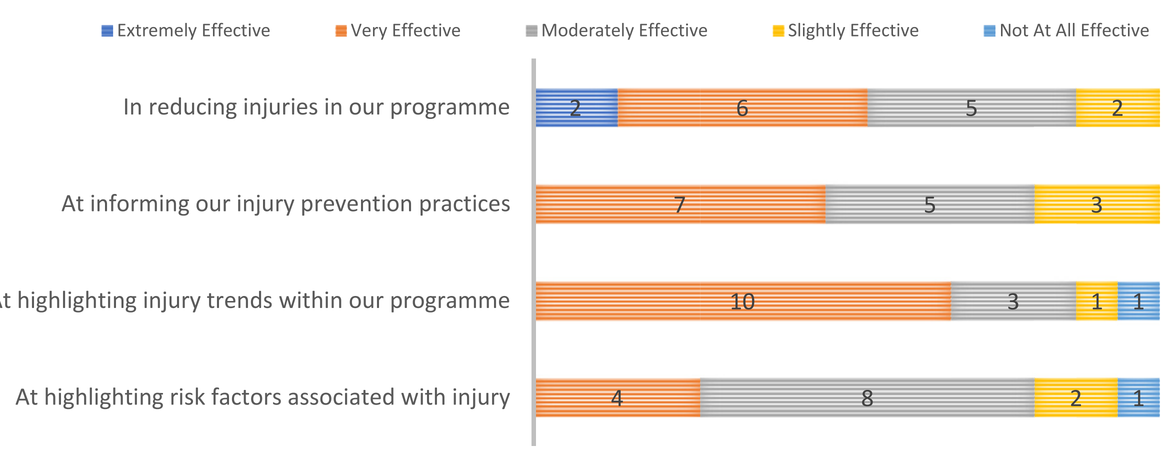

Fig. 2. Perceived effectiveness of injury surveillance practices in key situations as reported by 15 responders.

communication and a lack of engagement from the whole multidisciplinary team (MDT) were seen as significant barriers to conducting an effective injury surveillance system and are outlined with representative quotations in Table 2.

4. Discussion

The objective of this study was to identify the injury surveillance practices being used in competitive swimming environments, along with the nature of the data collected and the injury definitions being used. The perceived effectiveness of injury surveillance

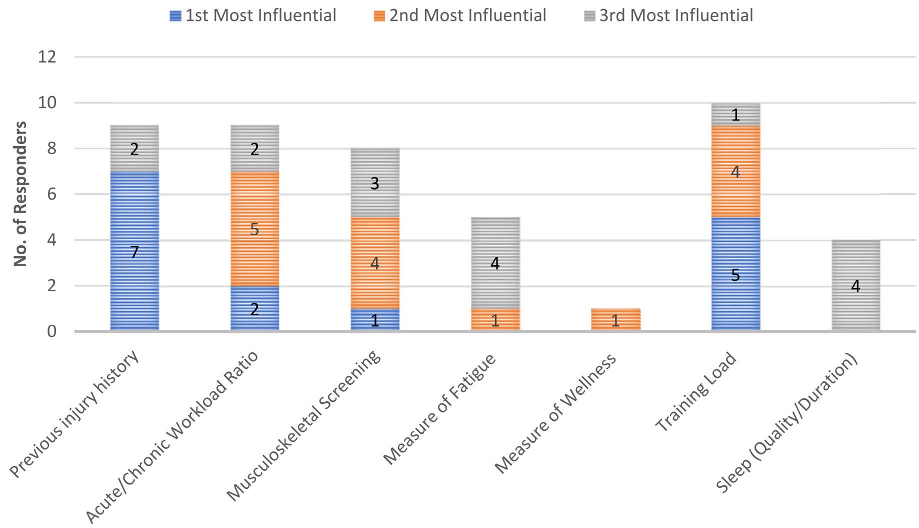

Fig. 3. Top three most influential data or metrics used for preventing injury as reported by fifteen responders.

Table 2
Thematic analysis of the key barriers and solutions associated with conducting an effective injury surveillance system, outlined with representative quotations.

Theme	Coding	Representative Quotes	Responder
Poor Communication	***Barriers***	*"A lack of effective communication with the coach/management team at the local program."*	R3
		"I may have 3 weeks with an athlete while competing overseas that I have not met before. They may come with no handover/medical history, no coaching guidelines and no report as to injury prevention practices and planned loading."	R3
		"Athlete reporting an injury in the first place"	R17
A Lack of Engagement		*"At the moment, our Head Coach doesn't monitor training load and doesn't entirely trust in its effectiveness"*	R10
		"Non-centralised sport - ensuring data accuracy from multiple different users"	R12
		"There is a culture of "coach knows best" at times, I find this difficult to gain decent traction in the injury prevention/management in the local squad, as I believe the coach feels I may be undermining his authority."	R3
		"Accurate load data being filled in"	R17
Improved Communication	***Solutions***	*"If we had an online platform with the swim trainer, the fitness coach, the doctor, the player and me to share all the information."*	R2
		"Communication among the high performance swim program in (country) is necessary for best practice."	R3
		"A cloud based application for coaches and athletes to upload data every day would be best for continuity of surveillance."	
Better Engagement		*"We get good compliance from medical staff, so details of an injury are well recorded. It would be ideal to match this data to training load and wellness data"*	R6

MDT = Multidisciplinary Team.

being able to highlight risk factors of injury, injury trends, informing injury prevention strategies and reducing the overall occurrence of injury was investigated. Finally, this study also examined barriers to injury surveillance.

4.1. Injury surveillance in competitive swimming

A key finding of this study was that 68% of responders employed injury surveillance practices within their swim programme. This number is lower than that of both amateur rugby clubs (91%) and schools rugby teams (86%), that did employ injury surveillance practices (Leahy et al., 2020; Yeomans et al., 2018). It is also lower than other forms of monitoring (training load) commonly used in competitive-level swim programmes (84%) (Barry et al., 2022). Injury surveillance is the first stage within the Translating Research into Injury Prevention Practice (TRIPP) framework and is highlighted as a key stage to inform all other aspects of the injury prevention paradigm (Finch, 2006). This discrepancy in uptake between swimming and rugby may be due to the higher risk of injury in a sport like rugby (King et al., 2019; Leahy et al., 2019) where the demand for systematic injury surveillance in contact sports may be higher than in non-contact sports. This may also be related to the nature of injuries sustained in swimming, which could be deemed as manageable. The majority of swimming-related injuries are non-time loss (Powell & Dompier, 2004) and may have a gradual onset (repetitive) (Trinidad et al., 2021). This often leads to swimmers training and competing with symptoms of injury, as outlined by Mountjoy et al. (2015), who reported that 70% of athletes attending the 15th FINA World Championships had symptoms of injury or illness in the weeks preceding and during the competition (Mountjoy et al., 2015). Despite these swimmers being compromised, they participated in training and competition but stated their performance was affected (Mountjoy et al., 2015). Swimming is a full-body sport, therefore specific modifications can be made to adapt the training programme to maintain a level of consistent training stimulus. In the event of non-time loss injury, many adaptations in the form of reduced training load, alteration of swimming biomechanics and the use of kickboards or pull-buoys can be introduced. The ability to manage a high proportion of injuries, while maintaining a full training programme in this manner may underestimate the burden of injuries in a swim programme. This may reduce the perceived need for injury surveillance in the sport of swimming, as demonstrated by the proportion of responders using injury surveillance in this study. However, an increased percentage uptake of injury surveillance practices in competitive swimming would lead to the improved design of injury prevention strategies as outlined in the TRIPP framework (Finch, 2006).

4.2. Injury definition

The injury definition used within an injury surveillance system can have a large impact on the reported outcomes (Bahr, 2009; Tabben et al., 2020), while the variability of definitions used across injury surveillance can limit the ability to compare outcomes (Bahr et al., 2020). A key goal of this study was to discover if the methodological inconsistencies highlighted in research also exist in a practical setting. The findings of the current study showed that the majority of responders used either the FINA (Mountjoy et al., 2016) or IOC (Bahr et al., 2020) definition of injury. Additionally, one responder used the 2014 AIS injury definition, one responder used a combination of both the IOC and FINA definitions and one relied on a custom definition. Previous epidemiological research has shown that methodological variation between studies limits the transferability of the findings (Trinidad et al., 2021). The call for a standardised injury definition to be used in injury surveillance is, without question, an essential requirement in a research context. Our findings show that the methodological inconsistencies seen previously are also present in the practical environment. However, the responders within this study highlighted that their primary goals of injury surveillance were, “to keep a record for insurance purposes”, “to analyse in relation to other training factors”, “to inform appropriate athlete training prescription” and/or “to highlight trends in injury occurrence”. The goal, “research purposes” was selected as a tertiary goal by only one responder. As research is not a goal in these environments, the research-practice gap may not be as significant as initially thought. In the practical environment (where research is not the goal), the injury definition needs to be consistent longitudinally to allow the injury surveillance outcomes to be compared season on season and between co-operating training centres/athletes. Long-term consistency in the selected injury definition will aid in the ability to evaluate the effectiveness of injury prevention strategies over subsequent seasons. If the injury definition were to change the data would not provide a reliable picture of the effectiveness of the interventions employed (Tabben et al., 2020). Similarly, a practitioner would also need to be aware of the definition they are using to select an appropriate epidemiological study to compare their results to (Meeuwisse & Love, 1997).

The definition selected by a practitioner must also be sport-specific and capture all the relevant issues affecting that programme. In a sport like swimming where non-time loss injuries are dominant, a time-loss injury definition would severely underestimate the true injury burden (Bahr, 2009). All 15 responders who participated in injury surveillance employed an injury definition that would capture non-time loss injuries adequately. However, the use of the IOC definition (selected by six responders), which includes the need for an injury or complaint to receive medical attention for it to be deemed a recordable event, may not be suitable. Even though a medical attention-based definition is preferred to the traditional time loss (Bahr, 2009; Bahr et al., 2020) as it captures a wider array of injuries and improves the quality control of recording, it still has its challenges (Toohey & Drew, 2020). The main limitation is the need for consistent and adequate access to a clinician who is briefed on the injury surveillance protocols. A suitable clinician may not always be available to assess an injury, particularly at all pool and gym training sessions, during international camps or competitions.

The findings of this study showed the role of recording the injuries primarily rested with the physiotherapist; however, the responsibility also fell on the swim coach, sports therapist, S&C coach or the athlete. The World Health Organisation (WHO) guidelines for injury surveillance (WHO, 2004) state that ideally, a member of the medical staff treating the injury should complete the injury surveillance record. However, they do acknowledge that administrative duties can add an unnecessary burden to medical staff and therefore a trained third party may also fulfil the role. This was deemed to be the case with many of our responders where a variety of staff recorded the data, but the majority of them had the injury diagnosis confirmed by a doctor or physiotherapist before being recorded. It is important to note that the FINA guidelines have broadened the scope of who can assess a medical attention injury. The guidelines state that a qualified clinician, including but not limited to a physician, physiotherapist, nurse or a physician assistant can be involved in the health care (not related to performance enhancement) of an athlete (Mountjoy et al., 2016). This better suits an applied environment where medical staff can often be contracted or part-time.

4.3. Method of data collection

The protocols and procedures of data collection have been shown to influence the outcome of sports injury surveillance in research (Bahr et al., 2020). The findings of this study showed that 13 responders used some form of electronic method to collect the data, whilst a relatively low number of responders used a formal injury classification system. The means of logging the information by use of pen and paper, electronically or online all have their merits and can be selected based on the specific context of the injury surveillance system, resources, level of implementation and objectives (Bahr et al., 2020). This point, however, is directly linked to the recommendation that a location, type and diagnosis of injury should be recorded (Mountjoy et al., 2016), allowing the grouping of data into higher-order classifications making reporting the data easier (Bahr et al., 2020). The recommended use of sport-specific classification coding systems (e.g., Sports Medicine Diagnostic Coding System (SMDCS), OSICS, etc.) would typically require an electronic database to ensure the effective and easy use of the system. However, in a less well-resourced setting, the use of pen and paper would suffice with the FINA consensus statement offering an alternative reporting method with less detailed options (Mountjoy et al., 2016).

The FINA consensus guidelines also provide detail on additional injury data which should be recorded. This additional detail allows the comprehensive classification of injuries into reoccurrences, re-injuries and exacerbations. Many additional data were collected by our responders during the recording process. The most frequent sub-categorisation of injury was an “overuse injury”. This is not a surprising result based on the frequent publication of epidemiological data highlighting that an overuse style injury is most common in swimming (Wanivenhaus et al., 2012). Despite the FINA guidelines presenting a user definition for sub-categorising injuries as either overuse or traumatic, they note that defining injuries using one or the other can be challenging. The categorisation of injuries according to their acute or repetitive nature and sub-categorising by sudden or gradual onset would provide more nuanced detail (Bahr et al., 2020). The addition of further detail according to the level of contact (direct, indirect and non-contact) would also give more context to the data. All responders in this study noted that they recorded additional details including date of injury and body location. The majority of responders collected mechanisms of injury, the impact of injury and injury diagnosis/type. The survey did not explore the categorisation of injury by the level of contact.

4.4. Data analysis

In sport, the era of collecting “big data” is now common and often involves routinely collecting biodata or training metrics, storing it longitudinally but not necessarily using it acutely (Arnold & Sade, 2017; Osborne & Cunningham, 2017). This was deemed to be the case in this study where only half of the responders conducted further analysis on the data after collection and the majority of responders highlighted the primary reason for recording the data was for insurance purposes (creating a medical record of the injury, documentation for medical costs etc.). This gives the impression that the data are being collected and stored, lest it is needed. Where further analysis was conducted, injury prevalence, injury incidence, injury per training exposure and injuries related to stroke or event were mostly employed. This is in keeping with the FINA consensus statement where the method of assessing exposure is outlined as either the calculation of incidence or prevalence and/or reported by stroke type or event distance (Mountjoy et al., 2016). The use of prevalence is the preferred method of expressing risk in a sport like swimming where chronic or gradual onset conditions are more frequent. (Bahr et al., 2020). In this study, injury prevalence was the most frequently used method of expressing risk, closely followed by injury incidence.

In a non-academic/research setting, the basic reporting of incidence and prevalence may suffice, particularly when disseminating the information to coaches and athletes. As the objectives of the injury surveillance system are elevated to investigate epidemiological trends more comprehensively, the level of detail would need to increase to reflect the outcome. Additional information to support the injury surveillance data were gathered by almost all of the responders, highlighting its perceived importance. Additional information collected included musculoskeletal screening, injury history, training load and wellness data. Neither the FINA nor IOC consensus statements include in-depth guidelines regarding the integration or implementation of athlete training load, wellness or biomechanical monitoring in parallel to the primary injury surveillance system. In a research context, training load or wellness monitoring are often tracked alongside injury surveillance (Eckard et al., 2018) and this is clearly common practice in a practical environment as found in the current study. The publication of guidelines on how to best integrate multiple monitoring systems in a practical environment may not only improve the standard of injury surveillance findings but also potentially improve the accuracy of injury prevention interventions.

4.5. Goals of injury surveillance

Responders highlighted that one of the primary goals of their injury surveillance was "to highlight trends in injury occurrence" and noted that they found injury surveillance to be very effective for this purpose. This finding is reinforced by a comprehensive study published in 2019 which investigated injury occurrence in the Japanese national swim programme over 15 years (Matsuura et al., 2019). The study highlighted an increase in knee joint injuries in the middle of the project which coincided with a change in start block dimensions (globally) leading to a potential increase in joint load. Longitudinal injury surveillance projects like Matsuura et al. (2019) can provide data to inform injury prevention interventions designed and employed in the practical environment.

Responders also highlighted that injury surveillance was very effective at informing injury prevention practices and moderately effective at highlighting risk factors associated with injury. This is also highlighted by Matsuura et al. (2019), where disc degeneration and spinal cramps of the lumbar region were identified as being common issues amongst Japanese swimmers. Once the issue was identified, a "Lumbar Injury Prevention" project was designed and implemented, resulting in a decrease in lumbar injury incidence during the intervention period. They identified key risk factors for injury during the surveillance period which included female gender, older age and increased years of swimming, and have targeted intervention programmes at young female swimmers to mitigate future injury in this population (Matsuura et al., 2019).

4.6. Barriers to injury surveillance

The successful implementation and effective use of an injury surveillance system are reliant on maintaining high standards in all aspects of the data collection and analysis procedures (Ekegren et al., 2014). In a sports setting where injury surveillance is not necessarily mandatory, upholding such high standards can be challenging (Ekegren et al., 2014). The barriers to injury surveillance in a practical swimming environment were identified during this study. A third of responders did not employ injury surveillance practices in their environment largely due to limited time, funding and compliance. Similarly, two-thirds of responders who did employ injury surveillance practices also acknowledged that limited time, funding and compliance were barriers they experienced. This finding is similar to that within amateur rugby where player adherence, time commitments, available medical professionals and system technical issues were cited as the key barrier to implementing injury surveillance at the amateur level of the sport (Yeomans et al., 2019).

Poor communication amongst, and a lack of engagement from, the whole MDT were also cited as key factors in conducting an effective injury surveillance system by responders. Responders noted that poor communication and adherence at the coaches/practitioner level was a challenge. In the primary training venue, poor communication amongst "home" staff was a barrier. This was also seen in non-centralised training centres or during competitions or camps where external coaches or practitioners may be employed. Poor communication amongst the MDT was also key findings in elite football across an eighteen year UEFA Club Injury Study (ECIS) (Ekstrand et al., 2019). The study found that levels of internal communication within an MDT was associated with injury rate and player availability. More specifically, poor communication quality between the head coach and the medical staff resulted in 6–7% lower player availability and 50% higher injury burden compared with teams with moderate to high communication quality. A similar study investigated the role of the head coach further and found that coaches with a democratic leadership style, and who supported and encouraged staff development were linked to a lower severe injury rate. (Ekstrand et al., 2018). This investigation into football and the similar themes found within this study highlight the importance of quality multi-disciplinary communication within the injury surveillance/prevention paradigm (Ghrairi et al., 2019). Based on this finding, it would be practical to suggest improved education on the importance of injury surveillance for all staff within the swimming programme (Ekegren et al., 2014). It may also be pertinent to present injury prevention strategies to a head coach in the guise of performance improvement. The relationship between injury burden and a team's success has been documented in elite football where athlete availability was associated with league rankings (Hägglund et al., 2013). In an individual sport context, a loss of training time due to injury was shown to be a determining factor in the obtainment of an athlete's performance goals in athletics (Raysmith & Drew, 2016). Studies of this nature may help educate and engage technical staff in the injury surveillance and prevention process.

5. Limitations

The survey was circulated globally through NGBs, coaching associations and social media outlets. This form of distribution limited the ability to track non-respondents and subsequently the response rate (as defined by Phillips (2017)) could not be calculated or presented. This also limits the ability to confirm the degree of international representation of the data. Additionally, as with all survey-based research, the presence of selection and response bias may have been present in this study. The authors opened the survey up to multiple avenues of distribution; however, it is likely that those who employ injury surveillance were more likely to engage with the survey than those that do not. Therefore, this may have inflated the data favourably towards those who do employ injury surveillance in their swim programme. The survey was also largely distributed through NGB channels, with a high proportion of responders working with international level athletes. The survey data may be more reflective of the upper-echelons of the sport with higher levels of resources to conduct injury surveillance. This may result in the data being less representative of the global landscape of injury surveillance in competitive swimming, particularly within grass-roots swim programmes. An additional limitation was the omittance of a survey question related to the categorisation of injuries by level of contact. As this is a recommendation of the FINA and IOC consensus statements it could have provided valuable detail but was not included in the survey. This is something that can be addressed in future research.

6. Practical application

The implementation of injury surveillance in a sporting context is related to the objectives of the system, the level of those under surveillance and the resources available. Where the injury surveillance outcomes are to be translated into research, it is imperative that strict use of the consensus guidelines is employed. The findings of this study showed that while many practical environments are collecting sufficient data (injury location, type and severity) the inconsistent use of injury definition and low engagement of classification coding systems limits the transferability or comparison of the findings. However, where research is not the objective, as discovered in the majority of cases, the requirement is to have a consistent and sport-specific injury definition longitudinally within the swim programme. In a sport like swimming where non-time loss injuries are dominant, a time-loss injury definition would severely underestimate the true injury burden (Bahr, 2009). To this end, the use of either the FINA or IOC injury definitions is appropriate. However, the inclusion of "medical attention" (as in the IOC definition) within the definition should only be considered when a consistent, trained medical professional is available to all aspects of the programme.

Similarly, the method of data collection is also resource-driven. Ideally, an electronic system could be used to reduce the time burden of injury surveillance and to improve the level of detail gathered. Preferably, a classification system would be employed with the date of injury, body location, mechanisms of injury, the impact of injury and injury diagnosis/type all being recorded. The categorisation of injuries according to their acute or repetitive nature and sub-categorising by sudden or gradual onset would provide more nuanced detail (Bahr et al., 2020), particularly in a repetitive sport like swimming. The collection of previous injury history and additional training load data were deemed to be very influential concerning preventing injury, potentially highlighting the need for it to be collected in parallel to the injury surveillance system.

7. Conclusion

A key finding of this study was that 68% of responders employed injury surveillance practices within their swim programme and only 53% of those performed further analysis on the data once it was collected. Injury surveillance is the first step in the TRIPP framework and the implementation of such a system requires the balance of following the sound principles outlined in consensus statements and overcoming the barriers associated with an injury surveillance system. The loftier the injury surveillance system objectives the more the guidelines need to be followed to maintain strict protocols and uphold the accuracy of the data. However, in a practical setting, it may be more prudent to tackle the "how" of implementing a system including roles and responsibilities of the MDT, the communication pathways, staff engagement and education on the necessities and benefits of injury surveillance. Those who do not partake in injury surveillance cite limited time, resources and funding as key barriers. The first step in increasing the uptake of injury surveillance in a swimming environment requires that these intertwined issues are addressed together. Injury surveillance models, where the implementation and integration are driven by the governing body, can be very successful in easing these barriers by providing tailor-made systems to domestic clubs and providing incentives for their participation (Yeomans et al., 2019). Additionally, providing staff education (Ekegren et al., 2014) as to the benefits of injury surveillance has been shown to improve coach engagement, particularly where the benefits are outlined with improvements to performance outcomes.

Ethics approval

Ethical approval was granted by the University's Ethics Committee (2019_10_09_EHS) and participants gave informed consent to their information being used for research and publication purposes.

Consent for publication

Approved.

Code availability

Not applicable.

Availability of data and material

Data and materials are available from the corresponding author, upon reasonable and appropriate request.

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Authors' contributions

All authors contributed to the review conception and design. Material preparation, data collection and analysis were performed by LB, TC, ML, KMcC and CP. The first draft of the manuscript was written by LB and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Declaration of competing interest

Authors declare that they have no competing interests. LB is an employee of Swim Ireland, but this does not constitute a competing interest.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ptsp.2022.07.001.

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