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Research article

Injuries in Medium to Long-Distance Triathlon: A Retrospective Analysis of Medical Conditions Treated in Three Editions of the Ironman Competition

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Abstract

Triathlon´s popularity is rapidly increasing, and epidemiological data relating to its related medical conditions is crucial to the development of proper medical plans and safety guidelines for it. This study examined the data from the medical reports collected during three consecutive editions of Ironman Italy, from 2017 to 2019. Out of 10,653 race-starters, 3.3% required medical attention sustaining 472 medical conditions. A significantly higher injury risk was found for females versus males ($\chi2 = 9.78$, $p = 0.02$) and in long-distance (IR: 4.09/1,000hours) rather than in Olympic/middle distance races (IR: 1.75/1,000hours). Most (68.4%) conditions (including muscular exhaustion, hypothermia, and dehydration) were systemic, whilst only 10.2% were acute traumatic injuries. Of a total of 357 triathletes requiring medical assistance, 8.1% were a candidate for hospitalisation. The equipment and personnel that are required for the medical assistance in future triathlon events were estimated based on Maurer's algorithm, and ten practical recommendations for triathlon medical support were formulated.

Key words: Muscle cramp, running, swimming, wounds, injuries, imaging diagnostics.

Introduction

Triathlon involves sequential swimming, cycling and running over different distances and under different technical conditions (Bentley et al., 2002). The international popularity of triathlon began to grow after its inclusion in the Sydney 2000 Olympic programme, and 120 national federations are affiliated to the International Triathlon Union (ITU) (International Triathlon Union, 2018). In the USA, the number of participants rose from 0.98 million in 2006 to 4.04 million in 2017 (Gough, 2020). The number of older (> 40 years) and female race participants has also notably increased (Lepers et al., 2013, Lepers and Stapley, 2019; Piacentini et al., 2019). USA Triathlon (USAT) - the American governing body of the sport - has registered a stabilisation in participation rate after the increase of the previous decade (Lauren, 2016). However, an increase in younger triathletes (under the age of 12), with a relative expansion of female participation, has been registered (Sherman, 2019; Lauren, 2016).

The aforesaid demographic modifications may result in changes in injuries and illnesses epidemiology. Understanding the incidence and the type of injuries and illnesses that are sustained during a triathlon race can be vital for the support of the dedicated rescue teams and sports medicine specialists' activity, assist in the direction of future preventive research, and the development of proper medical plans and safety guidelines (Gosling et al., 2008; Rimmer and Coniglione, 2012; Vleck, 2010; Vleck and Hoeden, 2020). However, few reports of the medical conditions related to triathlon events exist, and they often combine data from significantly different race distances (Kienstra et al., 2017). The shorter of these races can include half-length or shorter legs than the standard (Olympic distance) race format. Concurrent medium, long and super-long triathlon races that can take place within the same event involve segments that may be more than four times longer than those of Olympic distance races.

The primary goal of this study, therefore, was to report the participant demographics, the injury rate (IR) per 1000h of competition exposure, and to depict the kind and anatomical distribution of injuries that occurred during three consecutive editions of an international triathlon event that includes medium to long-distance race formats. The secondary aim of the study was to estimate the required personnel, vehicles, drugs and supplies, and formulate practical recommendations the development of proper medical plans for mass triathlon events.

Methods

The present study was approved by the local Ethical Committee (CEROM, Comitato Etico della Romagna; Prot. 4301/2019 I.592). The investigation centred on three consecutive editions of Ironman Italia between 2017 and 2019. Each edition included one long-distance triathlon. The 2018 and 2019 editions also included an Olympic distance race, whilst the 2019 edition also included a middle distance triathlon.

The demographic and medical data that were contained in both the participant registration forms and custom made race medical reports were examined. The pre-race registration forms included demographic data (name, gender, age). They also included medical data (i.e. any clinical history, chronic diseases, allergies,

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medication(s)) that would facilitate emergency medical staff interventions, in accordance with by ITU Competition Rules (International Triathlon Union, 2018) (Supplementary Material 1). The medical reports were relative to the medical assistance that was provided either during or after the end of a race. They included the exact diagnosis, the treatment or therapy administered, and the outcome of the injury (Table 1). Finally, the data relative to those meteorological conditions which may affect sports physiology (Gosling et al., 2008; Vleck and Hoeden, 2020) during a triathlon race (i.e. temperature, humidity, wind speed, rainfall) (Bergeron et al., 2012) were collected through the archive of the technological society Il Meteo (Il Meteo, 2020).

Supplementary Material 1. The pre-race form that the organisers used for the participants' data.

Bib number	Last name	First name	Age group	Country represented	Day phone	Medical conditions	Current medications	Allergies to medications	Hypersensitivities	Emergency contact name	Emergency contact phone

Table 1. Blank medical report form.

Date	Form N.	Bib Number:
		Rescue Location
Surname		Name

Birth Date	Sex	Cause	Ambulance Code	Patient Destination
	M | F	Illness | Trauma		
Driver			Rescuer	

A	Consciousness	Yes	No
	Free Airways	Yes	No
B	Absent breathing		
	Respiration rate		
	Saturation		
C	Absent circulation		
	Radial Pulse	Yes	No
	Heart Rate		
	Arterial pressure		

Objective Signs

☐ Agitation
☐ Headache
☐ Cyanosis
☐ Diarrhea
☐ Pain
☐ Hemorrhage
☐ Fever
☐ Tingling
☐ Nausea
☐ Paresis
☐ Emission of urine/faeces
☐ Deviated eyes
☐ Loss of consciousness
☐ Sweat
☐ Cough
☐ Dizziness
☐ Sickness
☐ Other…………………………..

Trauma/Lesion Description

☐ Skull	☐ Right Hand	**Major trauma**
☐ Front	☐ Left Hand	☐ Complex Extrication
☐ Nose	☐ Thorax	☐ Cockpit volume reduction
☐ Eyes	☐ Abdomen	☐ Ejection
☐ Mouth	☐ Pelvis	☐ Penetrating Wound
☐ Chin	☐ Upper limb (R)	☐ Fatalities in the event
☐ Cervical Spine	☐ Upper limb (L)	☐ Age <5 years
☐ Dorsal Spine	☐ Lower limb (R)	☐ Fall > 2m
☐ Lumbar Spine	☐ Lower limb (L)	
☐ Sacral Spine	☐ Right Knee	**Pre-existing pathologies**
☐ Right Shoulder	☐ Left Knee	☐ Cardiological
☐ Left Shoulder	☐ Right Ankle	☐ Respiratory
☐ Right Elbow	☐ Left Ankle	☐ Neurological
☐ Left Elbow	☐ Right Foot	☐ Abdominal
☐ Right Wrist	☐ Left Foot	☐ Other
☐ Left Wrist		

Measures

☐ Cervical collar	☐ Artificial ventilation
☐ Splint	☐ AED analysis
☐ Ked extrinsicator	☐ Shock
☐ Sedan chair	☐ External Cardiac
☐ Scoop stretcher/ Exell65	☐ Massage
☐ Vacuum mattress	☐ Circulation recovery
☐ Stretcher sheet	☐ Momentary
☐ Ice application	☐ circulation recovery
☐ Dressing	
☐ Thermal protection	
☐ Hyperextension of the head	
☐ Oropharyngeal cannula (Guedel)	
☐ Oxygen administration	

Prosthesis	☐ Emergency room ☐ Relatives or companion ☐ Police	Personal objects	☐ Emergency room ☐ Relatives or companion ☐ Police

Note

Return code |1|2|3| Modified return code |1|2|3|

Name of the triage nurse

The data were manually entered into Excel spreadsheets, while JASP (The University of Amsterdam, The Netherlands; https://jasp-stats.org) software was employed for the statistical analysis. Descriptive statistical analysis was applied to demographics and the anatomic anatomical distribution of injuries. The Student's t-test and $\chi 2$ were used to determine differences in medical conditions by age or gender. Pearson's product-moment correlation test was used to define the relationships between injuries and the gender, age group, race distance, and weather conditions.

In accordance with Italian Triathlon Federation (FITRI) rules, event participants were classified as amateurs (and sub-grouped into age categories) or professionals (Federazione Italiana Triathlon, 2020). Since some of the athletes participated in more than one race whilst others did not finish we used the race-starters as the denominator when calculating the injury rate. The injury prevalence rate (IR), in terms of injuries/1,000 race-starters, was calculated for each age group – taking gender differences into account. The IR was also estimated in injuries/1,000 hours-triathlon for the three long distance triathlons as well as for the two Olympic and the middle distance triathlons. For this purpose, the hours of triathlon were calculated as the sum of each athlete's race duration. When race-starters did not finish the race, the time was estimated as half of the average completion time. A severe IR was also calculated as the number of severe injuries/1000 race-starters: with *severe injuries* being defined as medical conditions that required hospitalisation. The data relative to each race were first considered separately in order to highlight race format related differences in injury profiles. Subsequently, the data were arranged in two distinct datasets, grouping the three long distances and those relative to the medium-race distances (i.e. the two Olympic and the middle distance) to highlight any differences between medium and longer race formats. The data on any medical assistance that was provided either to bystanders or to athletes who were not on one of the race start lists were presented separately.

To deal with the study's secondary goal, we first analysed the data relative to the drugs and dressings used to treat any medical conditions. The equipment and personnel required to optimise the medical assistance was calculated using a model that was based on Maurer's algorithm as prescribed by the Italian law on mass gathering emergency medicine organisation (Imbriaco et al., 2020; Neri, 2020). Maurer's algorithm is an easy-to-use, verifiable and reproducible scoring system that calculates an overall risk for mass events, based on specific supporting tables. According to the algorithm, risk factors are categorised into five groups, namely: 1) number of people (permitted and actual), 2) the event location (whether this in enclosed spaces or outdoors), 3) the potential for risk according to the type of event, 4) the participation of well-known figures, with security precautions, 5) consideration for police intelligence (Oberhagemann, 2017; Dirks et al., 2004; Maurer, 2001). To compile the algorithm with the required data, we used some additional data that were provided to us by the race organisers (i.e. the maximum capacity of the locality, public order matters, and estimation of the number of spectators for each of the three editions of the event).

Finally, each of the Authors (SN, GS, CC, EZ) who were involved as medical staff during the races created a list of recommendations based on their experience and the principles for safety and security at sports events that have been formulated by the Council of Europe (Council of Europe, 2015). We did not limit the number of recommendations: so as to allow each physician to address all aspects of the organisation and support without excluding those that may have appeared less relevant. Next, each of the physicians expressed their opinion on each of the recommendations. Any discrepancies between the authors were resolved through discussion until consensus was reached.

Results

The race distances and number of race-starters relative to the six races included in the present study are shown in Table 2. An overall number of 10,653 race-starters (9,165 males and 1,488 females) from more than 60 countries were included. A total of 94,611 triathlon-hours were covered, including 80,478 hours of long-distance, 10,336 of middle-distance and 3,797 of Olympic triathlon. The demographics of the participants are reported in Table 3. Female participation proved to be lower in the long-distance races (12%; n = 894) than in medium-distances (18.4; n = 594). No statistically significant weather conditions (reported in Table 4) were found between the races that were examined.

A total of 365 medical reports were evaluated, of which 122 were related to the year 2017, 140 to the year 2018 and 103 to the year 2019. Altogether, 359 participants (33.5/ 1,000 race-starters) required medical attention and sustained a total of 472 medical conditions. Some of the competitors sustained multiple injuries (Table 5). Overall, within the long-distance events, 332 participants presented 445 medical conditions. When the Olympic and middle distance races were considered together, 27 injuries, across 25 patients, were identified.

Table 2. Length of each segment and number of participants on the starting list of the six races that were included in the present study.

Type of race	Distances			Edition	Participants
	Swim (km)	Bike (km)	Run (km)		
Standard distance (Olympic)	1.5	40	10	2018	676
				2019	671
Middle distance	1.9	90	21	2019	1871
Long distance	3.86	180.26	42.195	2017	2562
				2018	2143
				2019	2730

Table 3. Age and sex of the participants. Age categories are expressed according to FITRI rules. (J: Junior; Ms; Master; P: Professional).

Cathegory	Age (years)	% of participants	Number	Sex (M/F; %)
J/S 1	18-24	1.4	154	76/24
Sr 2	25-29	6	641	80.3/19.7
S 3	30-34	12.3	1308	82.9/17.1
S 4	35-39	15.9	1692	86.2/13.8
Ms1	40-44	20.1	2142	88/12
Ms 2	45-49	19.6	2088	87.8/12.2
Ms 3	50-54	14.1	1505	86.6/13.3
Ms 4	55-59	6.2	665	87.7/12.3
Ms 5	60-64	2.1	221	90.5/9.5
Ms 6	65-69	0.6	61	86.9/13.1
Ms 7	70-84	0.2	25	88/12
	P	1.4	151	73.5/26.5
	Total	100	10653	86/14

Table 4. Weather conditions during each competition (Il Meteo, 2020).

	Air temperature (°C)			Humidity-(%)			Wind speed (km/h)		Rainfall
	min	max	med	min	max	med	med	max	
Long distance 2017	11	23	17	53	100	83	7	18	No
Long distance 2018	18	29	23	45	88	69	7	18	No
Olympic 2018	16	27	22	61	93	80	10	18	No
Long distance 2019	9	23	16	46	100	63	9	17	No
Olympic 2019 [1]	13	18	16	77	93	89	13	26	Yes
Middle distance 2019 [1]									

[1] Olympic 2019 and Middle distance 2019 took place on the same day.

Table 5. Conditions that were treated.

Medical condition	Number of injuries/Race distance					Total number of injuries
	Long 2017	Standard 2018	Long 2018	Standard/ Medium 2019	Long 2019	
Muscular exhaustion	105	6	29		4	144
Hypothermia	79				5	84
Dehydration			78		3	81
Abrasion	4	1	7	1	7	20
Blood pressure disorders [1]		1	2		10	13
Cervical pain					1	1
Drowning				1		1
Headache	1				1	2
Conjunctivitis					1	1
Muscle strain	4					4
Muscular cramps	6	1			3	10
Asthma				1		1
Articular Sprain	4					4
Overuse symptoms [2]			3	1	1	5
Low back pain					1	1
Chest pain					3	3
Ematuria					1	1
Plantar fascitis	2					2
Penetrating wound [3]				2	1	3
Fracture	1	1	1		1	4
Respiratory failure			1			1
mTBI			1	1		2
Gastroenteritis [4]				3	13	16
Bee sting	1					1
Jellyfish stings				3	24	27
Allergy		1	3		1	5
Contusion			2	3	5	10
Polytrauma			1			1
Dizziness					5	5
Blisters			1		4	5
Radiculopathy [5]			1		2	3
Total	218	11	130	16	97	472

[1] Including: hypertensive peaks, hypotension and syncope. [2] Including: articular pain. [3] Including one with foreign body, in a foot. [4] Including: abdominal pain, nausea, vomiting, and diarrhea. [5] Including: tingling, and sciatica.

The statistical analysis revealed a significantly higher risk of injury/illnesses in females ($\chi2 = 9.78$, $p = 0.02$). The risk of injury was also higher for long-distance races than it was in Olympic and middle distances ($\chi2 = 94.34$, $p < 0.00001$). No significant differences injury risk were found with athlete age-group ($p = 0.6$). According to the Pearson test, nor were there significant differences in the kind of injury that was sustained with age, gender or race distance. Out of a total of 472 treated medical conditions (Table 5), most (68.4%; n = 323) were systemic conditions: including muscular exhaustion, hypothermia, dehydration, blood pressure disorders and non-fatal drowning. On the contrary, acute traumatic injuries represented only 10.2% (n = 48) of the injuries; among them 37.5% (n = 18) were to the lower limbs, 16.6% (n = 8) to the upper limbs, 6.2% (n = 3) to the head, 2% (n = 1) involved the trunk while 25% (n = 12) had multiple anatomical distributions. In six cases, the anatomical location of the injury was unspecified. This likely occurred because of the arrival of too many cases for treatment at the same time.

Four fractures were reported: two to the collar bone, one to the hallux, and one to the nasal septum.

The medical reports also included eight cases of assistance being provided to bystanders. These consisted of one nose trauma, one dorsal strain, a panic attack, a penetrating wound in a finger, an allergic reaction, a spider-fish sting and two cases of jellyfish stings.

The IR in terms of injuries/1,000 hours-triathlon for long distance triathlon was 4.09 while for Olympic/middle distance races it was 1.75. The injury occurrences per 1,000 race-starters, for the different demographic groups, are reported in Table 6. Out of 357 triathletes requiring medical assistance, 91.9% (n = 328) were released in a mean time of two hours after treatment, 3.1 % (n = 11) were hospitalised for severe injuries, and 18 patients refused hospital admission; whilst 24.9% (n = 89) did not finish the race. The severe IR in the whole population was 1/ 1,000 race-starters; it dropped to 0.9 (n = 3) among Olympic/middle distance racers and was 1.1 (n = 8) for the long distance triathlons.

Only the data relative to the 2017 and 2019 events included the exact position of the rescue along the course; however, it was always specified in which of the three official assistance areas each patient was treated. Specifically, there were: an assistance point on the beach, one between the bike and running courses, and one advanced medical site itself consisting of three medical tents after the race finish line. We calculated that more than 91.4% of the assisted athletes were treated in the medical tent after finishing the race.

A comprehensive estimation of the medical material that was used for the medical assistance that was provided during the six races that were included in the present study is reported in Table 7. Considering a combined event made of a standard race, an Olympic and a long-distance (estimated athletes: 4,854; maximal capacity of the location: 30,000; overall expected persons: 15,000; famous personalities: 10; need to modify public mobility for the bike fraction) the Maurer's index calculated was: 45.3. This corresponds to a requirement of seven ambulances, 30 healthcare professionals and two medical units. The four doctors who were involved in the events shared the ten recommendations as reported in Table 8.

Discussion

The data that were collected during the three consecutive triathlon events covers more than 90,000 triathlon race hours and provides a unique epidemiological picture of triathlon-related conditions that require medical attention. As confirmed by the low rate of missing data, another relevant feature of the present study is that all the injury diagnoses were performed by physicians, thus enhancing reporting accuracy. The number of participants in the examined race series reinforces that triathlon races are mass-participation endurance events involving professionals and amateurs from 18 to 84 years and can generate a significant number of casualties (American College of Sports Medicine, 2004; Schwellnus et al., 2019).

Table 6. IRs among different demographic categories. Age categories are expressed according to FITRI rules (Federazione Italiana Triathlon, 2020) (J: Junior; Ms; Master; P: Professional).

Category		N. injuries/ race starters	IR x 1000 race-starters	IR ratio
J/S1 (18-24)		9/154	58.4	1.6
S2 (25-29)		23/641	35.9	1
S3 (30-34)		52/1308	39.8	1.11
S4 (35-39)		55/1692	32.5	0.91
Ms1 (40-44)		77/2142	35.9	1
Ms2 (45-49)		60/2088	28.7	0.8
Ms3 (50-54)		47/1505	31.2	0.87
Ms4 (55-59)		21/665	31.6	0.88
Ms5 (60-64)		7/221	31.7	0.88
Ms6 (65-69)		1/61	16.4	0.46
Ms7 (70-84)		0/25	0	0
P		5/151	33.1	0.92
Gender	M	287/9165	31.3	1
	F	70/1488	47	1.5
Race Distance				
Long distance		332/7435	44.7	1
Olympic/Middle distance		25/3218	7.8	0.17

Table 7. Estimated medical material used during six triathlon races.

Treatment	Long distance		Olympic/middle distance		Total	
	n	n x 1000 race-starters	n	n x 1000 race-starters	n	n x 1000 race-starters
Glucose solution	233	31.3	7	2.2	240	22.5
Physiological solution	167	22.5	7	2.2	174	16.3
Fans	55	7.4	11	3.4	66	6.2
Ice	15	2	5	1.6	21	2
Wound dressing	36	4.8	9	2.8	45	4.2
Antiemetics	22	3	1	0.3	23	2.2
Antihistamines	4	0.5	1	0.3	5	0.5
Cortisone	4	0.5	1	0.3	5	0.5
Bronchodilators	1	0.1	1	0.3	2	0.2
Antidiarrheal	1	0.1	1	0.3	2	0.2
Intubation kit	0	0	1	0.3	1	0.1

Table 8. Recommendations for the organization of medical support based on the analysis of the reported data and experience gained in the field.

Recommendation	Description/purpose
Institution of two advanced medical facility (AMF).	The medical tent (AMF 1) located near the start/finish line. A smaller one (AMF 2) located on the beach.
The constant presence of a public emergency operator in the AMF1.	Monitoring the situation and activating public emergency system whenever necessary.
Adoption of management software.	Updating the operative centre about the position of rescue resources along the track.
Implementation of an Advanced Command Post (ACP) along the track.	The ACP should include one or two public officials as advisors for the possible intervention of firefighters or the police whenever necessary.
Sea-rescues should be optimized considering the specific features of the swimming leg.	A motorboat at the centre of the swimming route should be equipped with: one emergency doctor, two nurses and two lifeguards. A lifeguard on personal watercraft should be placed every 200 m (a total of 15 in a long-distance). The number and professional profile of required healthcare personnel are not currently specified by the International Triathlon Union Guidelines (ITU, 2018).
The AMF 2 should be equipped with two doctors and a quad.	The physicians shall leave the AMF 2 on the quad for rescue on the beach whenever necessary.
The vehicles should be moved during the fractions of the competition.	During running, the quad (that was on the beach before), should be moved on the running path. One ambulance with one nurse and a driver rescuer should be located in the middle of the loop track. During the bike route, two ambulances with one nurse and a driver rescuer should be located respectively in the middle and at the end of the loop track.
20 beds should be predisposed in the AMF 1.	At least one location should be reserved for red codes while the others for yellow and green codes.
A specific rescue team should be identified for most severe conditions.	The team should include one physician, one nurse and one Basic Life Support Defibrillation (BLSD) volunteer rescuer. The same team should be dedicated to transfers to the hospital.
A briefing before race start and debriefing at the end of the first day of the race should be held.	To define roles and responsibilities and to define planning in case of maxi-emergency. The debriefing may help to optimize the organization for the next day/event.

The prevalence of injuries/illnesses requiring medical attention was 3.6% of total race-starters: ranging from 0.78% for those competing in the medium/Olympic race formats to 4.47% for those racing the long-distance races. This figure falls within the range of previous observations i.e. of 1.7% in Olympic and 17% in long-distance (Hiller et al., 1987). Race formats were risk ordered by distance, with long-distance exhibiting higher risk than Olympic and middle distance courses ($\chi 2 = 94.34$; $p < 0.00001$). This result was as expected since the Ironman involves a considerably different cardiopulmonary and musculoskeletal demands to Olympic and medium distance triathlons (Egermann et al., 2003).

The demographic data of the injured cohort showed that the incidence of medical conditions was especially high in under 24 years old involved in the long distance races. This result is consistent with the observation by Egermann et al., that the shorter was the total performance time, the higher the risk of an injury (Egermann et al., 2003).

As presented in Table 4, no significant differences in weather conditions were found between the examined races. It is a relevant result since most of the reported triathlon-related injuries and illnesses depend on weather conditions and their modifications, the most important variables being the temperature, the humidity, and the wind speed (Gosling et al., 2008). In particular, exhaustion, muscular cramps, and dehydration are favoured by hot climates, while bronchoconstriction and hypothermia are generally more common in cold climates (Kenefick and

Sawka, 2007; Knöpfli et al., 2007; Dallam et al., 2005; Maughan and Shirreffs, 2019). The temperature can also indirectly affect the occurrence of injuries. For example, since a high sea temperature may promote the occurrence jellyfish, it could increase the risk of jellyfish stings during the swimming leg (Molinero et al., 2005).

Regardless of the race format, most of the treated medical conditions in the present study affected female athletes (IR ratio:1.5; $\chi 2 = 9.78$, $p = 0.02$). On the contrary, no significant risk difference between males and females had been previously found within the Australian short-distance race series and during the Ironman Europe race (Egermann et al., 2003; Gosling et al., 2008). However, both these previous studies focused on musculoskeletal injuries only, without any mention of systemic conditions. Among the systemic conditions assessed in our study, there was hyponatremia, a condition that is prevalent among females (Urso et al., 2014; Laird and Johnson, 2012). The evidence of such a gender difference may be relevant from an epidemiological point of view, considering that female participation in triathlon competitions is expected to increase according to a report by International Triathlon Union (ITU) (Roethenbaugh et al., 2014).

Overall, in the present study, most of the treated conditions (70.2 %; n = 330) were systemic conditions induced by prolonged physical exertion and fatigue, including muscle exhaustion, hypothermia, dehydration or blood pressure changes. Acute and overuse injuries involving the musculoskeletal system represented 15.2% (n = 72). They were mainly localised to the lower limbs, the vast majority being minor injuries such as abrasions, contusions, ankle sprain, muscle strain, muscle cramps and plantar fasciitis. These results agree with those obtained among competitive triathletes (Williams et al., 1998; Korkia et al., 1994; Vleck, 2010; Vleck et al., 2014; Vleck and Hoeden, 2020).

In our series, a high number of skin-conditions (36%; n = 56), were treated, among which were many bites from marine animals; therefore, the use of wetsuits, already proposed to prevent hypothermia, could also be considered to prevent jellyfish stings (McHardy et al., 2006, Nikolić, 2020).

Our results confirm that most injuries encountered in the triathlon series are minor, with only a low percentage requiring hospitalisation. However, race organisers and medical personnel should be prepared at any time to cope with unpredictable eventualities, including the worst-case scenarios (Dobson and Barnett, 2008). For example, in our series, during the swimming leg of the middle-distance in the 2019 edition, a case of non-fatal drowning endangered a 27-year-old female. The dynamics involved a mild cervical trauma following the collision with another participant, precipitated by a condition of exhaustion and resulting in a temporary loss of consciousness. The patient was successfully treated with a prompt rescue on the beach, cardio-pulmonary resuscitation and intubation. Moreover we described a total number of ten cases of collapse (three non-severe) and two cases of hypotension. A collapse in endurance events can depend on many factors, including dehydration or postural hypotension, and non-severe cases are generally due to post-exercise hypotension; however, severe cases are most likely heat-strokes (Mora-Rodriguez et al., 2007).

Indeed, participants in medium to long-distance triathlon events are prone to hypothermia and hyperthermia. While hypothermia poses a moderate risk, and hypothermic patients must be dried, stripped and heated, on the contrary, hyperthermia is a life-threatening condition. The presence of elevated axillary temperature associated with disorientation, agitation and mental confusion poses a high risk of severe respiratory failure and malignant arrhythmias; therefore, patients may require sedation, intubation and muscle paralysis. In the present series, we did not encounter any severe cases of hyperthermia, probably because the mean environmental temperature was steadily under 23°C. Moreover, during the studied race series, the moderate and constant ventilation related to the coastal breeze cycle mitigated the effects of the high humidity rate (See Table 4) (Mora-Rodriguez et al., 2007).

In comparison, the range level of risk for heat injuries in medium to long-distance triathlon is 28-31°C (Gosling et al., 2008). The lack of data relative to water temperature limits the possibility to find any correlation to the high number of cases of hypothermia we reported in 2017. On the contrary, the high number of athletes suffering from dehydration in 2018 may depend on the average higher air temperature, exceeding more than five degrees the values measured during the other two editions.

The previously reported hospitalisation rate for triathlon-related medical conditions ranges between 2.1 and 3.2 %, while the hospital stays rarely exceed 24 hours (Gosling et al., 2010; Laird and Johnson, 2012; Yang et al., 2017). Rates favourably compare with the actual hospitalisation rate (3.1%) found in our study; however, in our series, the candidates for hospitalisation were 8.1% (n = 29).

In a perspective observation on the Kona Ironman triathlon, hospitalisation was mainly required for cardiac events, those traumas requiring imaging diagnostics or more treatment than simple suturing, and altered mental status with or without electrolyte abnormalities (Laird and Johnson, 2012). Based on our experience, patients should be immediately evacuated when suffering from: respiratory failure (respiratory rate > 30, SpO_2% <95%, objective breathing difficulty), blood pressure impairment (BP <90mmHg or >150mmHg; HR <50 bpm or > 120 bpm), heart attack, stroke (positive CPSS, speech disorders, unresponsiveness, loss of consciousness), allergic, hypo/hyperthermia (<35°C/>38.5°C).

Traumas should be hospitalised in major dynamics, severe injury in non-peripheral anatomic districts, and head injuries. Finally, triathlon related conditions requiring transfer to the local emergency room were consciousness impairment including disorientation, drowsiness, seizures or episodes of loss of consciousness.

Our series's IR ranged between 1.75 for the Olympic/middle distance races to 4.09 in long distances. The previous observance is challenging to compare because of the different definitions of injury or methods adopted. For example, in a questionnaire-based epidemiological investigation on British triathletes, the injury rate was 17.4 per 1000h of competition; notably, without difference between injury rates in long- and short-distance triathletes (Korkia et al., 1994). However, the authors included only musculoskeletal injuries, injuries to the eyes, teeth, nerves or concussion, and the data were collected over eight weeks. On the contrary, the race day-only studies may under-report orthopaedic complaints, especially overuse injuries, which are often underway for some time before the athlete notices the symptoms (Bahr, 2009). Despite being of paramount importance for the athlete's health and performance, most overuse injuries are probably irrelevant for medical assistance during or soon after the race. They are generally not considered separately from acute injuries in the organisation of a medical plan (McDonagh, 2014).

During a triathlon race series Gosling et al., found an IR of 20.1/ 1,000 hours (Gosling et al., 2010). However, that research included data from shorter race formats, including the Sprint discipline and the so-called "fun" triathlon, which may have different epidemiology from Ironman distances. Indeed in the Ironman, the race's length exposes participants to injuries, including dehydration and exhaustion, which are less likely to occur in shorter race formats (Laird and Johnson, 2012).

Some information may be derived from the reported epidemiological data to organise a medical plan for the medium to long-distance triathlon races. First, the medical equipment suppliers should consider glucose and physiological solutions (5%/500 ml), infusion set and ago cannulae, antiemetics and sheets for at least 5% of the total number of participants as necessities for each medical post.

Other material required includes isothermal rescue blankets, paper towels, CPR drugs, cortisone, painkillers and anti-inflammatory drugs. A defibrillator monitor, intubation set, sphygmomanometer, pulse-ox are also necessary. Concurrently, a portable ultrasound scanner may allow the execution of FAST examination and thoracic ultrasound, confirming many clinical conditions quickly, with the related medico-legal benefits.

ITU Competition Rules already include various prescriptions relative to weather conditions (ITU, 2018). In addition, some preventive measures formulated for shorter distances such as reducing race distance in case of hot weather conditions, mandatory use of a bottle during the cycle leg, more frequent drink stations and improved athlete education, particularly about heat-related illness and hydration, may also be applied to medium to long distances (Gosling et al., 2010). Temperature measurement should be carried out in all patients, and irrigation and ice application at the hemostasis points should be applied in case of hyperthermia.

Moreover, whilst a single physician was considered adequate to provide coverage in short-distance triathlons up to 2,000 participants per event day, for medium to long-distance race series, the presence of two doctors should be recommended (Gosling et al., 2010; Hiller, 2020). Furthermore, we confirmed Laird and Johnson's observation that more than 85% of the assisted athletes are seen at the medical post positioned after the end of the race, thus confirming the opportunity to place the main medical post after the finishing line (Laird and Johnson, 2012).

Since the swim may be the most lethal part of the event, as reinforced by our series where near-drowning was the only life-threatening condition, a second medical post should be placed on the beach (Laird and Johnson, 2012; Harris et al., 2010). Moreover, during the race, the participants tend to disperse along different parts of the track; therefore, one doctor and one nurse, equipped with four stretchers, should be located at the exchange point. Finally, an adequate number of support vehicles, including a quad vehicle, watercraft and ambulances, are essential to allow rescuers to move along the path quickly.

Another essential aspect to consider is that two per cent of the assisted people were bystanders, and half of them reported environmental-related conditions (i.e. animal bites and allergies). These issues highlight the importance of considering any specific location-related risk and hazards relevant to the spectators (Council of Europe, 2015).

This work presents some limitations. Firstly, we retrospectively analysed a consecutively collected series of data. Some data were missing despite the event organisers having predisposed the data collection in a uniform and reliable way to optimise medical assistance during future editions. For example, only the data relative to the 2017 and 2019 editions included the exact position of the rescue along the course. Besides, the physicians who filled in the medical reports number amongst the study authors- probably reducing interpretation biases.

Moreover, the data relative to the timing of the traumatic events were not available from all the reports, making it difficult to formulate specific recommendations to prevent the most common traumatic injuries. However, it was probably a minor limitation due to the modest contribution of trauma in terms of the number and severity of injuries sustained. Regardless, traumatic injuries had already been exhaustively discussed in previous research (Egermann et al., 2003; McHardy et al., 2006; Schorn et al., 2018; Steffen et al., 2019).

Finally, any generalisation of the results discussed must consider that they relate to a single location in a specific year period. Concurrently, different weather conditions can significantly change the number and type of triathlon-related medical conditions.

Conclusion

Triathlon races are mass-participation events with the potential to generate injuries and illnesses requiring medical attention, especially among inexperienced participants, females and athletes engaging in long distances.

Although most of the medical conditions encountered in this study were minor, some required hospitalization and the risk of fatal events cannot be excluded.

The most common conditions are physiological decompensation related to the prolonged effort and mainly have repercussions on the supply of necessary medical material and its location along the route. The most challenging situations that may be encountered include severe conditions, such as drowning and hyperthermia, and require a reinforced surveillance plan in the swimming fraction and the preparation of specific prevention and rescue plans.

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Key points

- Race formats were risk ordered by distance, with long-distance exhibiting higher risk than Olympic and middle distance courses.
- Most acute and overuse injuries involving the musculoskeletal system were localised to the lower limbs, and most were minor injuries including abrasions, contusions, ankle sprain, muscle strain, muscle cramps and plantar fasciitis.
- An advanced medical facility should be located near the start/finish line and a smaller one on the beach.
- For medium to long-distance race series, the presence of two doctors should be recommended.
- A portable ultrasound scanner may allow the execution of FAST examination and thoracic ultrasound, confirming many clinical conditions quickly, with the related medico-legal benefits.

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