Original Article

Injury Patterns and Frequencies Among Athletes at Ironman Langkawi 2024: Implications for Event Medical Preparedness

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Abstract

Introduction: Ironman Langkawi presents unique challenges due to high temperatures, humidity, and uneven terrain. These environmental stressors, combined with the intense physical demands of a 3.8-kilometer swim, 180-kilometer bike ride, and 42.2-kilometer run, lead to various injury risks. The event's stages correlate with specific injuries: swimming often results in exhaustion or water-related emergencies, cycling poses risks of abrasions and fractures, and running leads to musculoskeletal injuries and heat-related conditions. Understanding these patterns informs medical preparedness. **Methodology**: A retrospective observational analysis was used, with data gathered from Aid Station Medical Forms and Medic Base Treatment Forms, which recorded injuries and treatments at each event stage. Injury data were categorized for clarity, focusing on musculoskeletal injuries, trauma/skin injuries, heat-related illnesses, and other medical issues. This allowed a comprehensive view of the most common injuries and informed medical response needs. Ethical protocols ensured confidentiality, and standardized terminology improved data integrity. **Results**: A total of 1,760 athletes participated, with 1,273 competing in the full Ironman and 487 in the Ironman 70.3. A medical team of 110, including emergency physicians and paramedics, was strategically deployed. High humidity and tropical heat increased the likelihood of dehydration and heat-related issues. Out of 1,057 (60.1%) treated at aid stations, musculoskeletal injuries (e.g., cramps) were the most common, 986 (93%) cases. Trauma-related injuries, primarily during cycling, accounted for 22 cases. Medic bases recorded 118 (6.7%) cases, with 46 (39%) heat-related illnesses and 48 (41%) musculoskeletal injuries cases; 14 (11.9%) cases were referred to Hospital Langkawi for advanced care. **Discussion:** Findings underscore the impact of Langkawi's climate on injury patterns. Musculoskeletal injuries, notably cramps, were prevalent in the running stage, linked to prolonged exertion and heat. Musculoskeletal injuries such as fractures, abrasion and trauma injuries during cycling highlight risks in high-speed, uneven terrains. Comparisons with other endurance events affirm these trends. Improved hydration access and trauma-trained staff in cycling zones are recommended. Limitations include demographic data inconsistency and potential underreporting. Future research should standardize data collection, examine demographic injury correlations, and monitor long-term outcomes. **Conclusion**: Ironman Langkawi exemplifies the complex demands of tropical endurance events. The dominance of musculoskeletal injuries such as cramps in the running stage and fractures, abrasion and laceration wound during cycling aligns with patterns observed in similar events. Effective on-site treatment limited hospital referrals, validating the medical strategy. Enhanced hydration, safety measures for cyclists, and data standardization are recommended to improve medical readiness and injury prevention in future events.

Keywords: *endurance sports injuries, musculoskeletal injuries, heat-related illnesses, medical preparedness*

INTRODUCTION

Ironman triathlons are among the most challenging endurance events in the world, requiring athletes to complete a gruelling sequence of swimming, cycling, and running within a set timeframe. The standard Ironman triathlon consists of a 3.8-kilometer swim, a 180-kilometer bike ride, and a 42.2-kilometer run, which collectively test an athlete's physical and mental resilience [1]. These events often span several hours,

exposing participants to significant physical strain and environmental challenges such as heat, humidity, and uneven terrain, which vary by location [2].

The Ironman Langkawi event, held on the tropical island of Langkawi, Malaysia, introduces additional environmental factors that heighten the physical demands. High temperatures, intense humidity, and variable terrain increase the risk of heat-related illnesses, dehydration, and musculoskeletal injuries [3]. Athletes face compounded stress on their cardiovascular, respiratory, and musculoskeletal systems, which can lead to fatigue, electrolyte imbalances, and impaired judgment—all of which contribute to higher injury risks [4].

The endurance and intensity involved in Ironman events subject athletes to unique injury patterns, often stage-specific:

- **Swimming Stage**: The initial swim segment, often in open water, requires athletes to navigate strong currents, which can lead to exhaustion, cramping, and, in some cases, water-related emergencies such as jellyfish stings and near-drowning.
- **Cycling Stage**: As participants transition to the cycling phase, they encounter risks like muscle cramps, abrasions, fractures, and soft tissue injuries due to high-speed falls or collisions, particularly on sharp turns or challenging road surfaces.
- **Running Stage:** The final marathon-length run is particularly challenging due to cumulative fatigue, which increases the risk of musculoskeletal issues like muscle strains, sprains, and cramps. Environmental factors like heat stress can exacerbate fatigue and lead to serious conditions, including heat exhaustion and heat stroke.

These factors make Ironman events a complex setting for emergency medical teams, who must anticipate and manage a wide range of injuries and medical conditions. Understanding the specific types and frequencies of injuries common in Ironman events, particularly under unique environmental conditions such as those in Langkawi, is crucial for medical preparedness. This knowledge not only aids in effective on-site triage and treatment but also informs preventive strategies that can enhance athlete safety and performance in future endurance events.

METHODOLOGY

Design

This study was designed as a retrospective observational analysis, focusing on treatment data collected during the Ironman Langkawi 2024 event. This design enables a detailed examination of real-world data from a single event to identify injury patterns, frequencies, and potential factors associated with medical issues encountered during each stage of the Ironman triathlon. Observational analysis was chosen due to its suitability for analyzing events after they occur, allowing the research team to review medical records and treatments documented by on-site personnel without influencing the event itself.

Data source

The primary data sources for this study are two structured documents: the Aid Station Medical Form and the Medic Base Treatment Form. The Aid Station Medical Form captures data on each participant encounter at various aid stations positioned along the swim, cycle, and run stages of the course. This form documents essential details such as the participant's identification number, injury diagnosis, treatment provided, and final disposition, whether discharge or transfer to a medical base or hospital. Aid stations are strategically placed to provide immediate care and record incident details in real-time, allowing rapid response to injuries along the event course.

The Medic Base Treatment Form, on the other hand, records more extensive treatment data at centralized medical bases, which are equipped for more intensive interventions than aid stations. This form includes additional data fields such as participant ID, demographic details (age, gender, country of origin), injury diagnosis, and specific treatments administered (e.g., IV fluids, medications). Importantly, it also documents whether participants are referred to Hospital Langkawi, the designated receiving hospital for this event. Together, these forms provide critical data for understanding the types of injuries and treatments across different stages and care locations, enabling a comprehensive analysis of medical presentations throughout the event.

Data collection and processing

To ensure data accuracy and consistency, all entries from the Aid Station Medical Form and Medic Base Treatment Form were carefully reviewed and standardized. This data-cleaning process involved removing duplicate records, standardizing terminology for diagnoses, and verifying the completeness of each entry to maintain data integrity. Injury and medical conditions were categorized into broader, consistent groups for clarity and comparability. Diagnoses were grouped as follows:

Musculoskeletal Injuries, which included conditions such as muscle cramps, strains, sprains, abrasions, lacerations, and fractures, which were more commonly observed during the cycling stage; Heat-Related Illnesses and Dehydration, a category capturing conditions such as heat exhaustion and dehydration, typically influenced by environmental factors; and Other Medical Conditions, which included less specific symptoms like nausea and dizziness that required on-site care.

To assess the prevalence of each injury type, frequency counts were calculated for each category across all aid stations and medical bases. This approach allowed for a comprehensive understanding of the most common injuries and medical conditions encountered, providing insights into the specific needs and challenges faced by participants throughout the event.

Ethical considerations

To maintain participant confidentiality, all data were de-identified prior to analysis. The study was conducted in compliance with relevant ethical standards for retrospective data analysis, and no personal identifiers were included in the final analysis or publication.

RESULTS

Community description

The Ironman Langkawi 2024 event was held on the island of Langkawi, a tropical destination in the northwest of Malaysia with a permanent population of approximately 100,000 residents. Known for its scenic beaches, lush landscapes, and rich biodiversity, Langkawi experiences a significant influx of tourists, particularly during peak travel seasons and major events, which places added demand on local services.
The community is served by Hospital Langkawi, a minor specialist hospital equipped with essential emergency and medical facilities, including a 24-hour emergency department. Hospital Langkawi has a limited inpatient capacity (110 beds) and operates as the primary healthcare provider for both residents and tourists 5. Diagnostic services available include x-ray, ultrasound and CT scans, though advanced imaging options such as MRI may require transfer to hospitals on the Malaysian mainland. The hospital also features a helipad to support urgent medevac services to mainland facilities, with the nearest tertiary care hospital located approximately 70 kilometres away in Alor Setar, accessible by a 100-minute ferry and air ambulance transfer.

Langkawi's emergency medical response for this event included a collaborative setup with multiple aid stations, medic bases along the race course, and transport plans for participants needing higher levels of care. Ambulance services in Langkawi typically include one or two active ambulances, supplemented by on-call ambulances during high-demand periods. For the Ironman event, additional medical personnel and ambulances were strategically deployed to manage the anticipated surge in medical needs from participants, support staff, and spectators.

Climate and weather

On October 12, 2024, Langkawi experienced tropical weather conditions typical for October, with high temperatures and high humidity. The daytime temperature ranged between 27°C and 29°C [6] (about 81°F to 84°F), which is consistent with the island's usual climate in October, a month known for frequent rain. Langkawi typically sees an average of 19 rainy days in October, accumulating around 444 mm of rainfall across the month. The relative humidity tends to remain high, adding to the challenges for participants in endurance events like Ironman.

This combination of heat and humidity increases the risk of dehydration and heat-related illnesses, highlighting the need for adequate hydration and cooling measures throughout the event. These weather conditions make Langkawi both a picturesque but challenging environment for triathlon participants.

Number of athletes

For the Ironman Langkawi 2024, a total of 1,760 athletes participated, with 1,273 competing in the full Ironman-distance triathlon, which includes a 3.8-kilometer swim, a 180-kilometer bike ride, and a 42.2-kilometer run. An additional 487 athletes took part in the Ironman 70.3 (half-Ironman), consisting of a 1.9-kilometer swim, a 90-kilometer bike ride, and a 21.1-kilometer run. These endurance athletes represented various countries and tackled Langkawi's unique tropical challenges, including high humidity, intense sun, and intermittent rain.

Size, composition, and deployment of medical teams

For the Ironman Langkawi 2024, a substantial medical team comprising 110 personnel was deployed to ensure the safety and care of athletes throughout the event. This team included six emergency physicians, six drivers, 60 paramedics, and 38 nurses. The medical coverage was a collaborative effort between First Ambulance, a private ambulance provider, and the

Kedah State Health Department. Each organisation played specific roles, with First Ambulance overseeing the medical base at the swimming course and Kedah State Health Department overseeing medical bases and aid stations at the cycling and running courses.

First Ambulance provided 10 ambulances that were strategically placed around the running and cycling courses, utilizing a dynamic relocation strategy. This flexible approach allowed ambulances to be repositioned as needed across these segments, ensuring they could respond quickly to emergencies at any point along the course. Meanwhile, the Kedah State Health Department deployed four ambulances for static support at the cycling and running routes medical base, primarily designated for direct transfers from medical bases to Hospital Langkawi. This coordinated deployment strategy optimized response times and provided comprehensive coverage across the triathlon's distinct stages.

RESULTS OVERVIEW

Participant demographics and event overview

The age of participants treated at the Ironman Langkawi 2024 event ranged from 21 to 64 years. A total of 118 participants required medical attention, with a gender distribution of 91 male and 27 female athletes. The majority of participants were Malaysian; however, the event also attracted international participants from countries including Australia, the Philippines, Indonesia, Singapore, and Japan, reflecting the global appeal of the Ironman event in Langkawi.

It is important to note that demographic data collection differed by location. At the aid stations, only essential information such as the participant's registration number, diagnosis, treatment provided, and disposition was documented; no specific demographic details (e.g., age, gender, nationality) were recorded. Consequently, all demographic data presented here were sourced from medical base documentation, where comprehensive details such as age, gender, and nationality were routinely recorded.

Injury and ailment frequency

The types and frequencies of injuries varied depending on the stage of the event, with aid station and medic base records providing a comprehensive breakdown. At the aid stations, a total of 1057 (60.1%) participants seek treatment. Musculoskeletal injuries such as cramps and sprains were most prevalent, with a total of 9 (93%) cases recorded. Heat-related illness cases accounted for 16 (2%) cases. An additional 55 (5%) cases fell into other medical issue categories.

At the medic bases, 118 cases were recorded in total. Musculoskeletal injuries, primarily muscle cramps, abrasion and laceration wound accounted for 48 (41%) cases. Heat-related illnesses accounted for 46 (39%) cases, highlighting the need for increased hydration management at this stage. Other medical issues were 24 (20%) documented in the remaining cases, underscoring the variety of ailments experienced by participants.

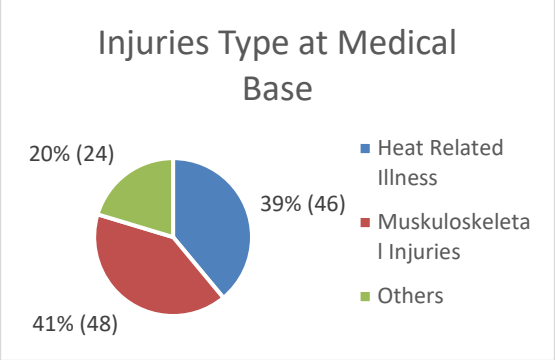

Figure 1: Injuries sustained at Medical Base

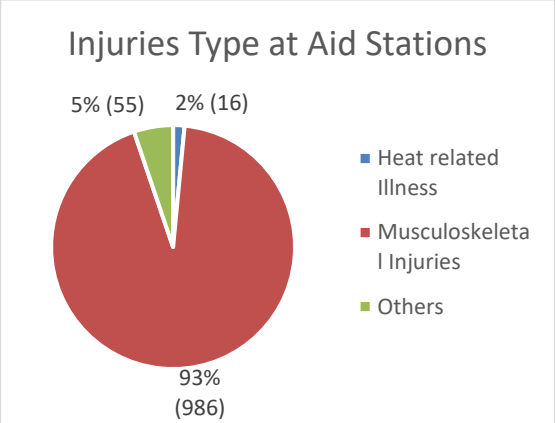

Figure 2: Injuries sustained at Aid Stations

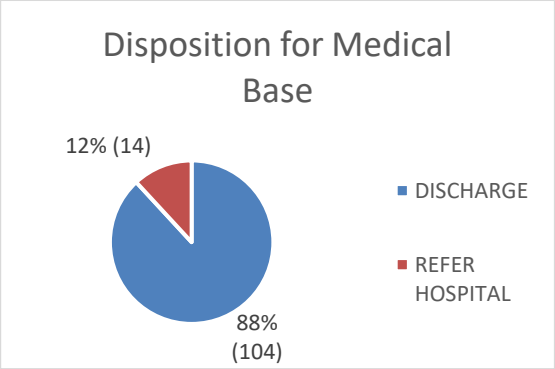

Figure 3: Disposition for Medical Base

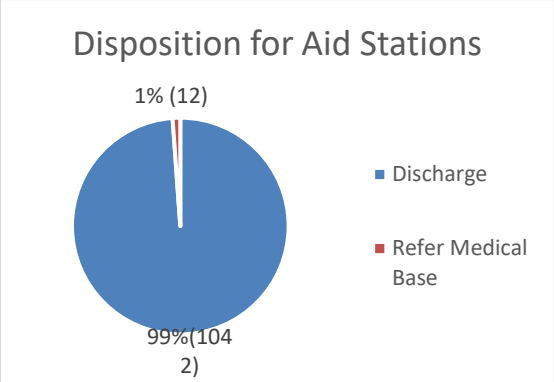

Figure 4: Disposition for Aid Stations

Frequency of presentations

A total of 1,057 cases were treated on-site at aid stations, while an additional 118 cases were managed at the medic bases. Of those treated at medic bases, 14 cases required further care and were subsequently referred to Hospital Langkawi. These referrals primarily involved severe trauma or dehydration-related issues that necessitated advanced medical intervention.

Treatment and disposition

A range of on-site treatments was provided to address common injuries and medical conditions. At the aid stations, Perskindol spray was the most frequently used treatment, with 662 applications, followed by LMS cream in 290 cases and ice pack with massage therapy in 105 cases. Minor treatments included dressings, bandaging, and vaseline applications, which addressed surface-level injuries and mild discomfort. At the medic bases, treatments were more diverse, including dressings, intravenous fluids, ice packs, massage, and other supportive care measures for more serious injuries and conditions.

Regarding patient disposition, the vast majority of cases managed at aid stations (1,045) were discharged after receiving treatment, while 12 cases were referred to medic bases for further assessment and care. At the medic bases, 104 patients were discharged after treatment, while 14 cases required hospital referral, primarily for conditions that exceeded on-site medical capabilities.

DISCUSSION

Interpretation of findings

The findings from Ironman Langkawi 2024 reveal distinct patterns in injury types and frequencies across the event stages, influenced significantly by environmental and physical demands. A high frequency of musculoskeletal injuries, particularly muscle cramps, was observed, especially during the running stage [7]. This aligns with the physical intensity and prolonged exertion required for the marathon segment, which, combined with the tropical climate and high humidity, increases the likelihood of dehydration and electrolyte imbalance—a primary contributor to cramping. The elevated humidity and high temperatures characteristic of Langkawi may have further exacerbated fatigue and muscle strain, emphasising the need for enhanced hydration strategies [8].

During the cycling stage, the incidence of trauma-related injuries, such as abrasions and fractures, was noticeably higher. This is consistent with patterns seen in other endurance events, where cycling presents risks of falls and collisions [9], particularly in challenging terrain or variable weather conditions. These findings underscore the importance of preparing for trauma care, especially in the cycling segment, as well as emphasizing bike handling skills and safety measures to participants.

Comparison with similar events

Comparing these findings to other Ironman and endurance events, a similar trend in injury types is observed. Studies on endurance races frequently report high rates of musculoskeletal injuries, particularly during the running stage, and trauma cases associated with the cycling segment [10]. Additionally, dehydration and heat-related illnesses are common in tropical climates or summer events, with participants often facing cumulative fatigue, dehydration, and heat exposure, which parallels the findings in Langkawi [11, 12]. This comparison reinforces the need for climate-adapted strategies and targeted medical support for endurance events held in tropical or humid environments.

Implications for medical logistics

The effectiveness of the medical support system at Ironman Langkawi 2024 was demonstrated through the high number of participants treated on-site and relatively few referrals to the hospital, suggesting that most injuries were managed effectively at aid stations and medical bases. However, based on the injury patterns observed, logistical adjustments could enhance future medical response. Increasing the availability of hydration stations along the course, especially near the running segment, could mitigate dehydration and muscle cramping. Additionally, positioning extra medical staff with trauma care skills along the cycling route would address the higher risk

of abrasions and fractures in that stage, ensuring rapid response to cycling-related injuries.

LIMITATIONS AND FUTURE DIRECTIONS

Limitations

One primary limitation of this study is the reliance on documentation practices that varied between aid stations and medical bases. While aid stations provided essential details such as participant registration numbers, diagnoses, and treatments, they did not record demographic data, limiting our ability to analyze age and gender trends comprehensively across all treatment locations. Consequently, demographic data were obtained solely from medical base records, which limits the generalizability of findings. Additionally, the absence of follow-up data on participants referred to Hospital Langkawi means that long-term outcomes, particularly for severe trauma cases, remain unknown.

Another limitation involves the categorization of injuries based on documentation, which may have led to inconsistencies in how injuries were reported. Minor injuries could be underreported, as some participants may have chosen not to seek treatment or self-managed mild symptoms. This underreporting could impact the overall understanding of injury prevalence and the specificity of findings.

Future directions

To address these limitations, future studies should aim to standardize data collection across aid stations and medical bases to ensure consistent and complete records of both demographic details and injury characteristics. Implementing a digital documentation system across all medical facilities could improve data accuracy, allowing for real-time entry and minimizing data loss. Additionally, follow-up studies focusing on the health outcomes of participants referred for advanced care would provide valuable insights into the long-term impact of endurance events on athlete health.

Future research could also examine specific demographic factors, such as age and gender correlations with injury patterns, to inform more personalized medical interventions and prevention strategies. Conducting a comparative analysis with similar Ironman events held in different locations could help identify context-specific risks, enabling the development of tailored medical strategies for endurance events in various settings.

CONCLUSION

The findings from Ironman Langkawi 2024 offer valuable insights into the types, frequencies, and management of injuries sustained in a tropical endurance event. Musculoskeletal injuries, primarily muscle cramps, dominated the running stage, likely due to the combined effects of sustained physical exertion and environmental conditions. Musculoskeletal injuries such as fractures, abrasion and laceration wounds, were more common during the cycling stage, underscored the risks associated with high-speed activities in endurance sports. These results align with injury trends observed in similar endurance events, suggesting common risk factors across triathlon disciplines.

The collaborative medical response, involving both dynamic and static ambulance deployments across the course, proved effective in managing on-site medical needs, with the majority of participants treated and discharged directly from aid stations or medical bases. This model highlights the importance of tailored medical logistics, including the placement of hydration and trauma support resources at key points along the course, to meet the demands of high-risk stages.

In preparation for future events, it is recommended that organizers adopt enhanced hydration and pre-race education initiatives, improve cyclist safety measures, and consider increased staffing in high-risk areas. Additionally, future studies could benefit from standardized data collection across all treatment locations and follow-up research on long-term outcomes for athletes requiring advanced care. These steps would contribute to a safer experience for participants, optimized medical readiness, and refined preventive strategies for endurance events held in diverse environments.

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