ORIGINAL ARTICLE

Sports-related injuries and illnesses during the Four Feathers Ultra Marathon 2020, Sabah: A retrospective study

Mohamad Azwan Aziz[1,2]*, Azmi Mohamed Nahar[1,2]

[1]Sports Medicine Unit, Faculty of Medicine, University of Malaya, Kuala Lumpur, Malaysia, [2]Department of Sports Medicine, University Malaya Medical Centre, Kuala Lumpur, Malaysia

ABSTRACT

Background: There were limited studies on the prevalence of injuries and illnesses among ultramarathoners.

Aim and Objectives: This was a retrospective study to describe the injuries and illnesses seen during Four Feather Ultra Marathon 2020, Sabah, held from 29th February 2020 to 1st March 2020, for future preparation of medical team standby.

Methods: All ultramarathoners who reported to the medical camp or on site with medical complains, and musculoskeletal complains were included in the study pools. There were 6 medical camp sites; KM10, KM19, KM36, KM51, KM62 and KM90.

Results: The incidence of injury was 504 per 1000 athletes, 478 per 1000 km run, and 401.4 per 1000 h run. There was no severe injury or medical illness that require urgent referral to a hospital. For minor injuries and illnesses, 54.3 % due to medical conditions, 39.8% due to musculoskeletal injuries and 5.9% due to skin conditions. For heat-related illness, 31.5% were heat cramps and 15.7% were heat exhaustion. 50KM category runners have the highest percentage of heat-related illness (78.3%) followed by 90km category (11.7%) and 20km category (10%). 74.2% (n = 89) of heat-related illness occurred at KM 19, 20% (n=24) occurred at KM 37, 2.5% (n = 3) at KM 50, and 3.3% (n = 4) at KM 70.

Conclusion: It is important to identify the early signs of severe heat-related illness. Thus, pre-planning medical standby is crucial to alert all medical staff during the event regarding symptoms and signs of heat-related illnesses during the event.

Key Words: Four Feather Ultra Marathon, ultramarathon, heat-related injuries, musculoskeletal injuries

***Address for correspondence:**
E-mail: letsgetfitdrazwan@gmail.com
Submitted: 28-Dec-2021 **Revised:** 07-May-2022 **Accepted:** 26-May-2022 **Published:** 11-Aug-2022

INTRODUCTION

Ultra Trail Marathon has gained popularity in recent decades with a geometric increase of 5200% in the number of runners from 1978 to 2008 (Hoffman and Wegelin, 2009). A study by Hoffman et al. (2010) showed a dramatic increase in the number of races offered and the number of official finishers from 1977 until 2008. Nevertheless, there were limited studies on injuries and illnesses amongst Ultra Trail Marathon runners during the competition. Vernillo et al. (2016) defined Ultra Trail Marathon as any foot race longer than 42.195 km performed on mountainous terrain involving elevation changes with <20% running on paved

Access this article online	
Quick Response Code:	Website: https://www.mohejournal.org
	DOI: 10.4103/mohe.mohe_33_21

How to cite this article: Azwan Aziz, M., Nahar, A. M. (2022). Sports-related injuries and illnesses during the Four Feathers Ultra Marathon 2020, Sabah: A retrospective study. *Malaysian Journal of Movement, Health & Exercise,11(1),*23-28.

or asphalt surfaces. Of these trails choose to challenge runners which include the rough terrain, elevation and descending rugged mountainous undulating surfaces, crossing over river and extreme weather (Parise and Hoffman, 2011; Hoffman et al., 2014). Zaryski and Smith (2005) described ultramarathoners as athletes that need rely on long-term preparation, sufficient nutrition, accommodation of environmental stressors and psychologic toughness.

Ultramarathoners are around the age of 40s, with a high experience in long-distance running, complete a longer duration of training, are well prepared, are goal oriented and love to push themselves to their limit (Khodaee and Ansari, 2012). Robust studies have shown that ultramarathoners have stable body weight and gain less weight as they are ageing (Hoffman and Fogard, 2012; Hoffman and Krishnan, 2014). Hoffman and Krishnan (2014) reported that ultramarathoners are healthier compared to the general population as a smaller number of serious illnesses are seen amongst ultramarathoners such as cancer, cardiovascular disease and its equivalent and diabetes. The number of absences of work or school is also less compared to the general population (Hoffman and Krishnan, 2014). This group of people have enormous physical and psychological demands as they need to push themselves to complete long-distance run, extreme weather and hurdles during the journey.

Four Feather Ultra Marathon 2020 in Borneo, Sabah, took ultramarathoners to the northern native villages at the foothills of Mount Kinabalu and around the mountain. The route had technical jungle sections at the night as well as a combination of steep terrain and technical trail sections, and the weather, mostly hot in the first part of the. The race started at Kiau Nuluh village located in Kota Belud, a 2-h drive from Kota Kinabalu. It is a picturesque village in the foothills of Mount Kinabalu, which is 600 m above sea level. Four Feather Ultra Marathon was divided into three categories: 20 km, 50 km and 90 km. For 20-km runners, they were experiencing elevation gain of 597 m and elevation loss of 1247 m. For 50-km category, they were experiencing elevation gain of 1892 m and elevation loss of 2539 m. For 90-km category, they were experiencing elevation gain of 3084 m and elevation loss of 3730 m. This Ultra Trail Marathon was medically covered by a sports medicine team, Hospital Queen Elizabeth, Kota Kinabalu, Sabah, consisting of two sports medicine specialists, five sports medicine medical officers, five medical officers trained in ultramarathon coverage and three physiotherapists. Each station was led by a sports physician or a senior sports medicine medical officer with three assistances comprising medical officers and physiotherapists.

To the authors' knowledge, there were limited studies on the prevalence of injuries and illnesses amongst ultramarathoners, especially Ultra Trail Marathon, which was held in Borneo, Sabah, as this area related to extreme weathers, and anticipation of animal or insect-related injuries in jungle area. The current study describes the injuries and illnesses seen during the Four Feather Ultra Marathon 2020, Sabah, for future preparation of medical team standby.

MATERIALS AND METHODS

Study design

This was an observational retrospective study. The data were collected from 29 February 2020 to 1 March 2020 during the event.

Participants

All ultramarathoners who reported to the medical camp or on-site from 29 February 2020 to 1 March 2020 with medical complaints and musculoskeletal complaints were included in the study pools. Officials who were treated for medical or musculoskeletal complaints were excluded from the study. There were six medical camp sites: at KM10, at KM19, at KM36, at KM51, at KM62 and at KM90.

Data collection

The data were collected using a universal sampling approach. All injuries and illnesses were recorded in standardised injury/illness report forms during the events, which include ultramarathoner's registration number, diagnosis, body parts injured, medical camp kilometres, absence of competition and treatment. Ultramarathoner's name and identification number were not collected and recorded in this study. Other demographic data such as gender, age and place of origin were obtained from the organiser based on ultramarathoner's registration number. All diagnoses and treatments were discussed and decided by a sports physician or a senior sports medicine medical officer, and the data were recorded in the injury report form. For heat-related illness, tympanic temperature was used instead of core body temperature to maintain patient's privacy and limitation of equipment for the measurement of core body temperature.

Definition of illness

Heat cramp and exercise-associated muscle cramp are interchangeable. According to Howe and Boden, 2007, heat cramp is the earliest sign of heat-related illness that manifests as painful muscle contractions around calf, thigh or abdominal muscle with normal or elevated core body temperature, but <104°F (40°C) (Howe and Boden, 2007). In our study, we diagnosed heat cramp when runners presented with severe cramp and flush and has body temperature >37.5°C. Other types of cramp considered are exercise-associated muscle cramp in this study. On the other hand, a diagnosis of heat exhaustion was considered if runners presented with extreme fatigue, dizziness, nausea, vomiting, fainting and a weak, rapid pulse with normal or elevated core body temperature, but <104°F (40°C) (Howe and Boden, 2007). Spectrum of heat-related illness is classified as below as in Table 1 (Lipman et al., 2013):

Data analysis

We performed a descriptive analysis on demographic data including age, sex, nationality, comorbidities, injuries and illnesses using IBM Corp. Released 2013. IBM SPSS statistics for Mac, version 22.0. Armonk, NY: IBM Corp. Injuries and illnesses were divided into three categories: musculoskeletal injuries, skin lesion and medical illnesses. The ultramarathoners were divided into three categories: 20 km, 50 km and 90 km.

We also analysed injuries and illnesses occurring at all medical checkpoints: KM10, KM19, KM36, KM51, KM62 and KM90 using descriptive analysis. We defined a rate of injury/illness as the number of injuries/illnesses per 1000 ultramarathoners, per 1000-km run and per 1000-h run.

The age of all ultramarathoners was not normally distributed using Shapiro–Wilk test (P = 0.00) and expressed as median and interquartile range (IQR). The age of ultramarathoners who sustained heat-related illness was normally distributed using Shapiro–Wilk test (P = 0.081) and expressed as mean and standard deviation.

Rate of injury/illness

Per 1000 ultramarathoners = [Number of injured ultramarathoners (n)/total number of participants (n)] × 1000

Per 1000-km run = [Number of km completed by injured ultramarathoners (km)/total number of km completed by participants (km)] × 1000

Per 1000-h run = [Number of hour completed by injured ultramarathoners (h)/total number of hour completed by participants (h)] × 1000

RESULTS

Five hundred and four ultramarathoners participated in the race: 221 ultramarathoners in 20-km race, 188 in 50-km race and 95 in 90-km race. Out of 504 ultramarathoners, 55 did not complete the race, 11 did not complete due to poor physical fitness and 34 were due to medical conditions. Twenty-three of 34 ultramarathoners did not complete due to heat exhaustion and 11 due to musculoskeletal injuries. 65.5% (n = 330) of ultramarathoners were male and 34.5% (n = 174) were female. The median (IQR) age for ultramarathoners was 37 ± 12 years. Four hundred and thirty-nine Malaysians (87.1%) participated in ultramarathons, while the remaining were international ultramarathoners. Fourteen ultramarathoners had underlying medical conditions; four had asthma, four had hypertension, two were breast cancer survivors, one was post-lung tuberculosis patient and one had underlying rheumatoid arthritis. Out of 504 ultramarathoners, 166 (33%) encountered at least one injury or medical illness during the race.

A total of 254 injuries/illnesses were encountered during the race. The incidence of injury was 504/1000 ultramarathoners, 478/1000-km run and 401.4/1000-h run, respectively as in Table 2. 54.3% were due to medical conditions, 39.8% due to musculoskeletal injuries and 5.9% due to skin condition. Details of injuries/illnesses are outline in Tables 3 and 4. There was no referral for emergency conditions, and all injuries and illnesses were treated pitch side and discharge.

For heat-related illness, 31.5% were heat cramps and 15.7% were heat exhaustion. The mean age of diagnosing heat-related illness

Table 1: Spectrum of heat related illness

Severity	Heat-related illness	Symptoms
Mild	Heat cramp	Cramps, moist and cool skin and normal body temperature
	Heat rash	Eruption of red papules or pustules, primarily on neck, upper extremities, trunk and groin
	Heat oedema	Limb swelling and facial flushing
Moderate	Heat syncope	Dizziness and transient blackout immediately following cessation of activity with normal body temperature
	Heat exhaustion	Raised in core temperature 38.3°C–40°C with symptoms such as dizziness and transient blackout immediately following cessation of activity
Severe	Heat stroke	Raised core body temperature of>40.5°C with altered mental status, seizures, coma, tachycardia, hypotension and hyperventilation

Table 2: Incidence of injuries in per 1000 athletes, per 1000 h, per 1000 km

Incidence of injuries and illnesses	Total	Category		
		20 km	50 km	90 km
IR/1000 ultramarathoners	504	153.8	957.4	421
IR/1000 h	401.4	682.5	567.3	265.7
IR/1000 km	478	788.9	565.2	354

IR: Incidence rate

Table 3: Demographic data for injuries and illnesses

Demographic data for injuries and illnesses	Total runner, n (%)	20-km runner (n)	50-km runner (n)	90-km runner (n)
Gender				
Male	169 (66.5)	13	132	24
Female	85 (33.5)	21	48	16
Nationality				
Malaysia	211 (83)	29	147	35
International	43 (17)	5	22	5
Injury/illness category				
Medical illness	138 (54.3)	20	102	16
Exercise fatigue	7 (2.8)	7	0	0
Dehydration	2 (0.8)	1	0	1
Heat cramp	80 (31.5)	11	61	8
Heat exhaustion	40 (15.7)	1	33	6
Gastritis	7 (2.8)	0	7	0
Musculoskeletal	101 (39.8)	12	68	21
Exercise-induced cramp	68 (28.8)	8	40	20
Meniscal injury	1 (0.4)	0	1	0
Patellofemoral syndrome	2 (0.8)	0	2	0
Sprain	18 (7.1)	4	12	2
Strain	14 (5.5)	0	14	0
Skin				
Abrasion	5 (2)	0	3	2
Blister	6 (2.4)	2	3	1
Laceration	4 (1.6)	0	4	0

Table 4: Injury and illness categories in different medical stations

Injury/illness category	Station km 10	Station km 19	Station km 36	Station km 51	Station km 62	Station km 90
Medical illness						
Exercise fatigue	0	7	0	0	0	0
Dehydration	1	1	0	0	0	0
Heat cramp	0	74	2	0	4	0
Heat exhaustion	0	15	22	3	0	0
Gastritis	2	1	3	1	0	0
Musculoskeletal						
Exercise-induced cramp	28	35	2	1	2	0
Meniscal injury	0	0	1	0	0	0
Patellofemoral syndrome	1	0	1	0	0	0
Sprain	11	3	4	0	0	0
Strain	0	0	5	9	0	0
Skin						
Abrasion	0	1	2	1	0	1
Blister	2	2	1	0	1	0
Laceration	0	1	2	1	0	0

was 40.3 ± 9.1 years. There were 71.7% of males and 28.3% of females. 50-km category ultramarathoners had the highest percentage of heat-related illnesses (78.3%), followed by 90-km category (11.7%) and 20-km category (10%). 74.2% (n = 89) of heat-related illnesses occurred at KM19, 20% (n = 24) at KM36, 2.5% (n = 3) at KM51 and 3.3% (n = 4) at KM62.

DISCUSSION

Recent decades have shown an exponential rise in ultramarathoners including Malaysia (https://statistik.d-u-v.org, 2020). A total of 22 ultramarathon races had been held in Malaysia alone in 2020, with over thousands of participants overall (https://statistik.d-u-v.org, 2020). Despite that, little that we know regarding the injury risk and injury pattern. Thus, this study is a stepping stone to provide an important information regarding the pattern of injuries seen in ultramarathon in Malaysia. To the authors' knowledge, this is the first reported study on ultramarathon injuries held in Sabah. With a rising number of international ultramarathon events held in the tropical region including Sabah, it is important for the organiser to understand the pattern of injuries and illnesses that could occur during the race, to help better medical preparation in the future. The rates of injuries in this study were lower compared to Vigolana Trail® 2014 (1885.7 per 1000 runners, 13,153.9 per 1000-h run) and RacingThePlanet® 4 Deserts Ultramarathon Series from 2005 to 2006 (3860 per 1000 runners) (Vernillo et al., 2016; Krabak et al., 2011). Vernillo et al. (2016) only included 77 out of 234 ultramarathoners with total injuries and illnesses of 132. Hence, the incidence of injuries is expected to be higher compared to our study, 166 out of 504 ultramarathoners. Krabak et al. (2011) examined 257 out of 396 ultramarathoners in a multistage event of total 240-km distance. Thus, that explains the higher incidence of injuries and illnesses compared to our study which only involve maximum of 90-km distance (Krabak et al., 2011).

The most common injuries reported were exercised-induced cramps (28.8%). Muscle cramps were commonly reported injuries in many studies (Vernillo et al., 2016; Krabak et al., 2011; Millet et al., 2011; Scheer and Murray, 2011). This is due to pathophysiology of exercise-induced cramps is explained by Millet et al. (2011) and Scheer and Murray (2011) due to neuromuscular fatigue. Yokozawa et al. (2007) concurred that body mechanism to maintain neuromuscular balancing during the race increases in the risk of muscle damage and cramping. Rapid alternate eccentric–concentric contraction for neuromuscular balancing worsens muscle damage (Skenderi et al., 2006). Rhabdomyolysis, which is commonly seen in endurance sports demonstrated by an increase in myoglobulin and creatine kinase (Hoffman and Krishnan, 2014). However, that was not seen in our study. Higher risk of rhabdomyolysis is seen in extreme environmental temperature, dehydration and use of non-steroidal anti-inflammatory drugs (Hoffman and Krishnan, 2014; Krabak et al., 2011). Krabak et al., 2011 recommended that runners who presented with excessive cramping or excessive fatigue should be investigated for acute kidney injury on medical tent using urine samples: clusterin, cystatin-C, cysteine-rich protein 61 (CYR-61) and urinary B2M (Krabak et al., 2011). Nevertheless, this bedside urine test is an expensive test and was not available during the events. We would recommend this bedside urine test in future event as it can help in early detection of acute kidney injury which needs a prompt treatment with fluids and referral to hospital. Ultramarathoners suspected with acute kidney injury should be promptly referred to the emergency department for further management.

Heat-related illness, heat exhaustion and heat cramps were the most reported medical conditions during the race. Heat-related illness is caused by an imbalance of heat production, heat absorption from the environment and efficiency of thermoregulatory mechanisms. The WetBulb Globe Temperature (WBGT) index is an ideal index to assess the environmental risk of heat-related illness, but it was not available during this event. Thermotolerance of an individual is based on multiple risk factors: poor physical fitness, obesity, dehydration, poor acclimatisation and external load, including clothing, equipment and protective gear (Larry Kenney et al., 2012). In our study,

71.7% (n = 86) of heat-related illnesses were male and 28.3% (n = 34) were female similar to many studies (2019; Carter et al., 2005). However, a recent systematic review (2020) found that female-armed force is a higher risk of getting exertional heat-related illness, while male-armed force was a higher risk of heat stroke (Alele et al., 2020). The highest number of heat-related illnesses occurred at KM19 and KM37 (74% and 20%) where the ultramarathoners received the maximum sunlight. The average daytime temperature during the event was 79°F with humidity of 86%. Low temperatures at altitude and during the nights also minimised the level of heat stress during ultra-endurance races, which explained the low percentage of heat-related illnesses at km 50 and 70 (https://www.timeanddate.com/weather/malaysia/kotakinabalu/historic?month=2&year=2020; Bongers et al., 2015). Furthermore, studies by Hue et al., 2014, concluded that a shorter distance with higher exercise intensity leads to high risk of getting hyperthermia compared to low intensity with longer running distance (Hew-Butler et al., 2015). Poor acclimatisation should be considered the main risk factor for heat-related illness. The ideal duration for acclimatisation is 2 weeks for maximum adaptation; it decreases in heart rate, skin and rectal temperature and increases in sweat rate and work capacity (Periard et al., 2015). Heat cramp is one of the earliest signs of heat-related illness. The pathophysiology behind heat cramp is excessive sweat after prolong heat exposure leads to loss of sodium leading to muscle cramp (Howe and Boden, 2007). Thus, the mainstay of treatments includes ice therapy, stretching and rehydration (Howe and Boden, 2007). Failure to recognise heat exhaustion during the race can lead to catastrophic events: heat stroke and death. Often, these runners presented with nausea, vomiting, headache or dizziness (Howe and Boden, 2007). Removal of ultramarathoners from hot environment and aggressive cooling to lower down body temperature is necessary with adequate fluid resuscitation (Howe and Boden, 2007). Out of 40 ultramarathoners, 17 marathoners completed the race before the diagnosis of heat exhaustion was made after their visit to the medical camp. Adequate preparation medical standby is crucial to prevent severe complication of heat-related illness. Pre-medical standby preparation included (1) education regarding early recognition athletes with moderate-to-severe heat-related illness and early removal of the athletes to medical standby personnel; (2) emergency kits and equipment such as cold normal saline, continuous supply of ice packs and fan; (3) location of medical standby near the river and (4) education to the ultramarathoners regarding heat-related illness. During medical standby, each medical tent was led by a sports physician or senior sports medicine medical officer to help in early recognition, early removal and early treatment of moderate-to-severe heat-related illness. With this preparation, we manage to prevent severe heat-related illness complication and all athletes were treated at pitch side and discharge without a need to refer to hospital.

We observed that 50 km ultramarathoners had a higher incidence of injuries per 1000 ultramarathoners. Many of them suffered from heat-related illness and exercise-induced muscle cramp, suggesting the lack of preparation in terms of physical and mental compared to 90 km ultramarathoners. This is because many of ultramarathoners were amateur, inexperience and newly ventured into the world of ultramarathon. With good strategy and experience and adequate preparation, 90 km ultramarathoners had the lowest incidence rate per 1000 ultramarathoners, 1000 km distance and 1000-h run. Hence, that is why there was less injury after KM51.

Ultramarathon-related injuries have been shown to burden the health and economy of a runner. It is estimated that the total economic burden of RRIs was at €172.22 (95% confidence interval [CI]: 117.10–271.74) per running related injuries and €1849.49 (95% CI: 1180.62–3058.91) per 1000 h of running (Hespanhol et al., 2017). Thus, it is crucial to tackle risk of injuries for ultramarathoners and pre-planning on medical standby before the race. In this study, with adequate preparation of medical standby, which include adequate staffs and trained personals, adequate medical and medical equipment, proper medication, early education regarding heat-related illness to staff and participants, early recognition and early removal of ultramarathoners suspected with heat-related illness could save their life. However, the authors want to outline that there are few limitations of this study. This study only examined the ultramarathoners who seek treatment at our medical base camp located at km 10, 19, 37, 50, 70 and 90. Other treatments outside the medical camp were not recorded in this study. Many ultramarathoners did not seek medical teams and self-treated their injuries or illnesses. Thus, this could lead to the low incidence of injuries in this study. There were limited on-site investigations available to confirm some diagnoses such as rectal temperature to know the exact core temperature to diagnosed heat-related illness. This study was unable to demonstrate the risk factors of developing injuries and illnesses, especially with the alarming numbers of heat-related illnesses in this study. WBGT should be used to calculate the environmental temperature, and if the environmental temperature is alarming, safety measures should be taken to reduce the number of heat-related injuries. Further studies should be conducted to examine the physical, psychological and other environmental factors contributing to the injuries for future improvement in preventive measure of injuries and heat-related illnesses. A follow-up in sports medicine clinic should be done to see the outcome of the injuries on daily activities of living.

CONCLUSION

The most common ultramarathon-related injuries seen in the Four Feathers Ultra Marathon were muscle cramps (28%). The most common medical illnesses reported were heat-related illnesses, heat cramps and heat exhaustion. One of the most important pre-planning medical standbys in Sabah should include preparing for heat-related illness. With adequate medical standby planning, there were no severe heat-related illnesses that prompted any referral to the emergency department. Early recognition, early removal and early treatment will help improve the outcome of heat-related illness and prevent the development of severe heat-related illness such as heat stroke.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

REFERENCES

Alele, F., Malau-Aduli, B., Malau-Aduli, A., & Crowe, M. (2020). Systematic review of gender differences in the epidemiology and risk factors of exertional heat illness and heat tolerance in the armed forces. *BMJ Open*, *10(4)*, e031825.

Bongers, C. C., Thijssen, D. H., Veltmeijer, M. T., Hopman, M. T., & Eijsvogels, T. M. (2015). Precooling and percooling (cooling during exercise) both improve performance in the heat: A meta-analytical review. *British Journal of Sports Medicine*, *49(6)*, 377-384.

Carter, R. 3rd., Cheuvront, S. N., Williams, J. O., Kolka, M. A., Stephenson, L. A., Sawka, M. N., & Amoroso, P. J. (2005). Epidemiology of hospitalizations and deaths from heat illness in soldiers. *Medicine & Science in Sports & Exercise*, *37(8)*, 1338-1344.

Hespanhol Junior, L. C., van Mechelen, W., & Verhagen, E. (2017). Health and economic burden of running-related injuries in Dutch trailrunners: A prospective cohort study. *Sports Medicine*, *47(2)*, 367-377.

Hew-Butler, T., Rosner, M. H., Fowkes-Godek, S., Dugas, J. P., Hoffman, M. D., Lewis, D. P., Maughan, R. J., Miller, K. C., Montain, S. J., Rehrer, N. J., Roberts, W. O., Rogers, I. R., Siegel, A. J., Stuempfle, K. J., Winger, J. M., & Verbalis, J. G. (2015). Statement of the Third International Exercise-Associated Hyponatremia Consensus Development Conference, Carlsbad, California, 2015. *Clinical Journal of Sport Medicine*, *25(4)*, 303-320.

Hoffman, M. D., & Fogard, K. (2012). Demographic characteristics of 161-km ultramarathon runners. *Research in Sports Medicine*, *20(1)*, 59-69.

Hoffman, M. D., & Krishnan, E. (2014). Health and exercise-related medical issues among 1,212 ultramarathon runners: Baseline findings from the ultrarunners longitudinal TRAcking (ULTRA) study. *PLoS One*, *9(1)*, e83867.

Hoffman, M. D., & Wegelin, J. A. (2009). The Western States 100-Mile Endurance Run: Participation and performance trends. *Medicine & Science in Sports & Exercise*, *41(12)*, 2191-2198.

Hoffman, M. D., Lebus, D. K., Ganong, A. C., Casazza, G. A., & Van Loan, M. (2010). Body composition of 161-km ultramarathoners. *International Journal of Sports Medicine*, *31(2)*, 106-109.

Hoffman, M. D., Pasternak, A., Rogers, I. R., Khodaee, M., Hill, J. C., Townes, D. A., Scheer, B. V., Krabak, B. J., Basset, P., & Lipman, G. S. (2014). Medical services at ultra-endurance foot races in remote environments: Medical issues and consensus guidelines. *Sports Medicine*, *44(8)*, 1055-1069.

Howe, A. S., & Boden, B. P. (2007). Heat-related illness in athletes. *The American Journal of Sports Medicine*, *35(8)*, 1384-1395.

Khodaee, M., & Ansari, M. (2012). Common ultramarathon injuries and illnesses: Race day management. *Current Sports Medicine Reports*, *11(6)*, 290-297.

Krabak, B. J., Waite, B., & Schiff, M. A. (2011). Study of injury and illness rates in multiday ultramarathon runners. *Medicine & Science in Sports & Exercise*, *43(12)*, 2314-2320.

Larry Kenney, W., Wilmore, J.H., & Costill, D.L. (2008). *Physiology of sport and exercise* 5th ed. (5th ed.). Champaign, IL: Human Kinetic.

Lipman, G. S., Eifling, K. P., Ellis, M. A., Gaudio, F. G., Otten, E. M., & Grissom, C. K. (2013). Wilderness Medical Society practice guidelines for the prevention and treatment of heat-related illness. *Wilderness & Environmental Medicine*, *24(4)*, 351-361.

Millet, G. Y., Tomazin, K., Verges, S., Vincent, C., Bonnefoy, R., Boisson, R. C., Gergelé, L., Féasson, L., & Martin, V. (2011). Neuromuscular consequences of an extreme mountain ultra-marathon. *PLoS One*, *6(2)*, e17059.

Parise, C. A., & Hoffman, M. D. (2011). Influence of temperature and performance level on pacing a 161 km trail ultramarathon. *International Journal of Sports Physiology and Performance*, *6(2)*, 243-251.

Periard, J. D., Racinais, S., & Sawka, M. N. (2015). Adaptations and mechanisms of human heat acclimation: Applications for competitive athletes and sports. *Scandinavian Journal of Medicine & Science in Sports, 25* (Suppl 1), 20-38.

Retrieved from https://statistik.d-u-v.org. [Last accessed 2020 Dec 20].

Retrieved from https://www.timeandate.com/weather/malaysia/kotakinabalu/historic?month=2&year=2020. [Last accessed 2020 Dec 31].

Scheer, B. V., & Murray, A. (2011). Al Andalus Ultra Trail: An observation of medical interventions during a 219-km, 5-day ultramarathon stage race. *Clinical Journal of Sport Medicine*, *21(5)*, 444-446.

Skenderi, K. P., Kavouras, S. A., Anastasiou, C. A., Yiannakouris, N., & Matalas, A. L. (2006). Exertional rhabdomyolysis during a 246-km continuous running race. *Medicine & Science in Sports & Exercise*, *38(6)*, 1054-1057.

Update: Heat illness, active component, U.S. Armed Forces, 2018. *MSMR*. 2019 Apr;*26(4)*, 15-20. PMID: 31026173.

Vernillo, G., Savoldelli, A., La Torre, A., Skafidas, S., Bortolan, L., & Schena, F. (2016). Injury and illness rates during ultratrail running. *International Journal of Sports Medicine*, *37(7)*, 565-569.

Yokozawa, T., Fujii, N., & Ae, M. (2007). Muscle activities of the lower limb during level and uphill running. *Journal of Biomechanics*, *40(15)*, 3467-3475.

Zaryski, C., & Smith, D. J. (2005). Training principles and issues for ultra-endurance athletes. *Current Sports Medicine Reports*, *4(3)*, 165-170.