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Full Length Research Paper

Common ultramarathon trail running injuries and illnesses: A review (2007-2016)

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Regardless of the significant growth of ultra-marathon trail-running races over the last 40 years, epidemiological research is lacking. Presently, no review paper exists that integrates the empirical surveillances of ultra-marathon trail runners' injuries and illnesses. The purpose of this work is to integrate the empirical findings of injuries and illness among trail runners during the period 2007-2016. An electronic database search was conducted using Pubmed, Medline, Science Direct, Ebscohost, Biomed, CINAHL, Embase and Sabinet according to PRIMSA guidelines. The search identified a high injury and illness prevalence among ultra-marathon trail runners. Unfortunately, the injury and illness definition adopted by the studies was heterogeneous, which makes quantifying literature challenging. It is recommended that a homogenous definition of ultra-marathon trail-running injury and illness be drafted. The most prevalent injuries were dermatological (foot blisters, subungual hematoma, chafing and lacerations) followed by musculoskeletal (plantar fascia, ankle, Achilles tendon, knee, lower back and thigh). Common medical illnesses include muscle damage, fatigue, cramps, and cardiorespiratory dysfunction. South Africa hosts a very busy trail-running calendar, but one epidemiological investigation has been conducted among its runners and none in its neighbouring African countries. It is recommended that more quantitative and qualitative investigations be undertaken.

Key words: Ultramarathon trail, musculoskeletal injury and illnesses, dermatological injuries of ultramarathon trail runners.

INTRODUCTION

The popularity of ultra-marathon trail-running has grown in stature parallel to ultra-marathon road races (Hoffman and Wegelin, 2009). Hoffman et al. (2012) reported that a geometric increase of 5200% in the number of runners and ultra-marathon trail races had taken place during the period 1978 to 2008. Ultra-marathon trail race is defined as any foot race longer than 42.195 km performed on a mountainous terrain involving elevation changes (Vernillo et al., 2016).

The International Trail Running Association requires that the route entails a minimum of 20% or less running on paved or asphalt surfaces (Malliaropoulus et al.,

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2015). These off-road trails include diverse single footpaths, ascending and descending rugged mountainous undulating surfaces, travailing across rivers and dense grasslands (Hoffman and Parise 2010). In spite of these extreme environmental challenges, it also serves as the fundamental lure which attracts runners to try something different from the tedious dull road races (Hoffman and Fogard 2011). Ultra-marathon trail running does cause muscle damage, which has been identified by inflammatory markers (Easthope et al*.,* 2010; Denissen et al*.,* 2012; Hambleton et al*.,* 2016).

Factors contributing to muscle damage include exercise intensity, eccentric muscle contractions, extreme environmental temperature and subsequent dehydration (Clarkson et al*.,* 2006; Casa et al*.,* 2010). There has been eight reviews examining the running injuries and illnesses of road marathon and ultra-marathon runners during the period of 2007 to 2016 (Khodaee and Ansari, 2012; Krabak et al., 2014; Saragiotto et al*.,* 2014; Kluitenberg et al*.,* 2015; Van der Worp et al*.,* 2015; Yamato et al*.,* 2015; Hoffman, 2016). A consensus guideline statement has been published on the medical strategies primarily for the application by the ultra-marathon race managers (Hoffman et al*.,* 2014).

South Africa has a busy trail foot race calendar, hosting 102 ultra-marathon trail races, of which there are six popular ultra-marathon trail races with great following of runners (Cottrell, 2016). Unfortunately only one empirical epidemiological investigation has been conducted by Denissen et al*.* (2012) on ultra-marathon trail running in South Africa and on the African continent. The large number of South African trail races might benefit from this paper to draft medical strategies and guidelines to assist with the immediate emergency management of medical injuries and illnesses that befall runners.

To date, no systematic review has been published on trail-running injuries and illnesses aimed at educating runners, coaches, sport scientists and sport medical practitioners. Therefore, this review focuses specifically on documenting the common musculoskeletal injuries and illnesses and their mechanisms among ultra-marathon trail runners.

METHODOLOGY

The authors followed the standard practices for systematic reviews (PRIMSA). The definitions were guided by the PRIMSA checklist for participants, interventions, comparisons, outcomes and study designs (PICOS). The participants were ultra-marathon trail races; the intervention was not necessarily a therapeutic intervention but is interpreted as an exposure, namely injuries and illness of ultra-marathon trail running. The outcomes of interest were (i) occurrence of injuries and illnesses among trail runners, (ii) occurrence of injuries and illnesses among ultra-marathon trail runners, (iii) musculoskeletal injuries among ultra-marathon trail runners, (iv) dermatological injuries among ultra-marathon trail runners.

The exclusion criteria were (i) publications prior to 2007, (ii) studies pertaining to ultra-marathon road runners, (iii) musculoskeletal injuries and illnesses pertaining to road ultra-marathon runners, (iv) dermatological injuries of road ultra-marathon runners, (v) non-English papers, (vi) non-peer reviewed papers and (vii) tertiary level students and adults. Publications prior to 2007 were excluded because the authors wanted to draw a definitive conclusion on the latest 10 years of research in this area.

A literature search of peer-reviewed and professional journal publications was conducted through the search engines, Google scholar and CrossRef in the following databases: Pubmed, Medline, Science Direct, Ebscohost, Biomed, CINAHL, Embase and Sabinet (Figure 1). Key search words were ultramarathon trail, musculoskeletal injury and illnesses, dermatological injuries of ultramarathon trail runners. The screening eligibility of papers was performed in the following three steps; (i) title screen, (ii) abstract screen and (iii) full text screen. Figure 1 displays the synthesis of literature.

RESULTS AND DISCUSSION

Eight thousand seven hundred and eighty-six publications were identified. However, after stringent evaluation in accordance with the exclusion criteria only 22 publications were utilised for this review (Figure 1).

Hierarchy of evidence and quality appraisal

The Hierarchy of Evidence was adapted from Abdullah et al*.* (2009). All publications were filtered based on the appropriateness of their title and whether they met the inclusion criteria. The hierarchy of the level of all the publications was determined based on the application of the appraisal tool cited in Abdullah et al*.* (2009). The authors included all levels of evidence as long as the publications met the inclusion criteria. All publications were independently appraised by the authors. Differences in opinion between reviewers were discussed until consensus was reached (Table 1). The results of the literature search are synthesized into Table 2, which describes the chronological overview of ultra-marathon trail-running injuries during the period 2007 to 2016. The discussion will be categorised into: definition of injury and illnesses, and prevalence of ultra-marathon trail-race injury and illnesses.

Definition of injury and illness

Injury and illness definitions were heterogeneous in nature, which increases the challenge of reviewing ultra-marathon trail-running epidemiological investigations (Scheer and Murray, 2011; Malliaropoulos et al*.,* 2015; Vernillo et al*.,* 2016). Malliaropoulos et al*.* (2015) and Hespanhol et al*.* (2016) did not define what a running-related injury and/or illness is, but inferred it from the symptom of pain, duration of pain, severity of pain and the anatomical site of pain based upon the runner's recall

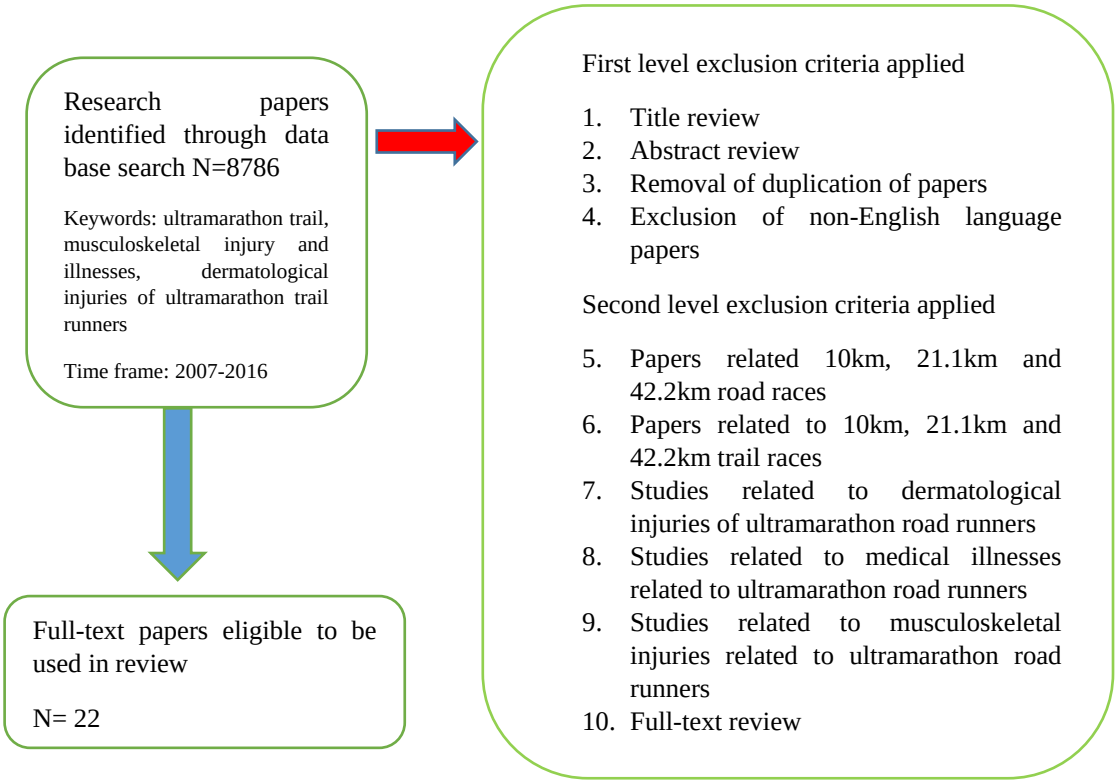

Figure 1. The synthesis of the literature review process.

of injuries. It is recommended that a consensus statement be drafted to provide a homogenous definition of ultra-marathon trail-running injury and illness, which concurs with Lopes et al. (2012).

Running-related injury and illness prevalence

Running-related injury and illness occurrence varied from 22 to 31% (Malliaropoulos et al., 2015; Hespanhol et al., 2016). The overall injury/illness rates vary from 18.9-1885.7/1000 runners (Krabak et al., 2011; Verniollo et al., 2016). Running-related injuries and illnesses are categorised into medical illnesses, dermatological and musculoskeletal injuries. Common medical illnesses include muscle damage, fatigue and cramps, while dermatological injuries entail foot blisters, subungual hematoma, chafing and lacerations (Hespanhol et al., 2016; Vernillo et al., 2016). The vulnerable sites of musculoskeletal injury are plantar fascia, ankle, Achilles tendon, knee, lower back and thigh.

Common medical conditions

Muscle fatigue and cramping are predisposed by a fast running pace and the consistent effort made to maintain a steady running pace and balance up and down mountainous footpaths (Yokozawa et al., 2007; Denissen et al., 2012; Degache et al., 2014).

Millet et al. (2011) and Scheer and Murray (2011) concur that ultra-marathon trail running produces neuromuscular fatigue, which facilitates exercise associated muscle cramping. Eccentric muscle contractions produce greater muscle damage and cramping (Degache et al., 2014). In an attempt to maintain balance the agonist, antagonist and stabilizer muscles of the core, lower limb especially the ankle inverters are eccentrically hyperactive to reduce the incidence of falls, which increase the risk of muscle damage and cramping (Yokozawa et al., 2007). Further the sudden rapid change from eccentric to concentric contraction to maintain balance increases the muscle damage, producing fatigue and cramping (Skenderi et al., 2006; Saugy et al., 2013; Degache et al., 2014).

Endurance sports are synonymous with muscle damage, which is identified by elevated creatine kinase and myoglobin concentrations (Hoffman et al., 2014). Extreme environmental temperature, dehydration, use of non-steroidal anti-inflammatory drugs (NSAID) during the race increases the severity of the muscle damage, thereby increasing the risk of acute kidney injury. It is recommended that runners regularly rehydrate during the race and refrain from the use of NSAID (Krabak et al.,

Table 1. Hierarchy of evidence (Abdullah et al., 2009).

Levels	Type of research design	Number of studies
Level 1	Systematic review	Nil
Level II-1	Randomised control trials	Nil
Level III-1	Pseudo randomised controlled trial	Nil
Level III-2	Comparative study with concurrent controls	Nil
Level III-3	Comparative study without concurrent controls	21
Level IV	Case series/studies with either post-test or pre-test/post-test outcomes	1

2011; Hoffman et al*.,* 2014). Runners who experience excessive muscle cramping and/or excessive fatigue should visit the medical tent to evaluate their urine (Krabak et al*.,* 2011). If urine sample has the following biomarkers present: clusterin, cystatin-C, cysteine-rich protein 61 (CYR-61) and urinary *B*2M, it is suggestive that the runner is experiencing acute kidney failure induced by distance running, which constitutes a medical emergency (Krabak et al*.,* 2011). Therefore Hoffman et al*.* (2014) recommend that medical strategies need to be in place to treat acute kidney injury induced from distance running.

Dermatological (skin) injuries

Foot blisters are a common malady of ultra-marathon trail races representing 33-74% of skin injuries (Scheer and Murray, 2011; Lipman and Krabak, 2012; Vernillo et al*.,* 2016). Most of these injuries are minor but can adversely affect running performance (Hoffman and Fogard, 2011). Medical management of painful non-bloody foot blisters is aspiration, thereby ensuring the preservation of the overlying skin. Caution should be practised when aspiring the bloody foot blisters because of the increased risk of infection. The occurrence of subungual hematomas ranges from 3-15% among runners (Scheer and Murray, 2011; Vernillo et al*.,* 2016). It is recommended that runners should seek medical assistance when attempting to aspire them. Treatment involves piercing the skin at the tip of the nail or through the surface of the nail with a clean wide bore hypodermic needle or heated paper clip (Hoffman et al*.,* 2014). Although foot blister and subungual hematoma care can be self-treated, the use of medical resources and personnel during and after races is high (Hoffman et al*.,* 2014). Therefore it is recommended that the medical personnel assisting during ultra-marathon trail races be knowledgeable about common foot-race dermatological injuries and have emergency medical supplies well-stocked.

Musculoskeletal injuries

The major musculoskeletal injury is overuse. However, acute injuries do occur. Overuse musculoskeletal injuries are not serious but adversely affect running performance. Acute musculoskeletal injuries such as knee and ankle sprains require immediate medical attention. Most common running-related injury diagnoses are ankle sprains, plantar fasciitis, Achilles tendinopathy, patellofemoral pain syndrome and iliotibial band friction syndrome (Malliaropoulos et al*.,* 2015; Vernillo et al*.,* 2016). The most vulnerable anatomical sites to injury are plantar foot, ankle, Achilles tendon, knee and lower back. Emergency on-field medical attention must be administered for acute musculoskeletal injuries (PRICE) (Gotlin, 2008). It is also recommended that injured runners consult a biokineticist for appropriate final-functional phase rehabilitation to prevent acute injuries becoming chronic and for rehabilitation of the aforementioned injuries.

Hydration concerns

Appropriate nutritional and fluid management is essential for the successful completion of any ultra-marathon race. Regular and an appropriate amount of fluid and electrolyte replacement are the runners' responsibility. In an attempt to avoid exercise-associated hyponatremia, runners are advised to replenish fluids lost by following the drink-to-thirst-strategy. During the race, elite runners generally adopt a scientific method of drinking a prescribe amount of rehydrate solution at regular intervals so as to replenish lost fluids. Dehydration has a high prevalence among endurance athletes, which adversely affects their performance, health and well-being (Cuthill et al*.,* 2009; Lebus et al*.,* 2010).

High-altitude sicknesses

There are three primary high-altitude sicknesses that medical staff at ultra-marathon trail races should be aware of. They include acute mountain sickness (AMS), high altitude cerebral edema (HACE) and high altitude pulmonary edema (HAPE). The ultra-marathon trail epidemiological investigations during 2007-2016 did not report on AMS and HACE. Vernillo et al. (2015a) identified HAPE as a serious sickness that affects the

Table 2. Chronological overview of ultra-marathon trail-running injuries (2007-2016).

Authors /Country	Participants (mean age/ race distance)	Findings
Cuthill et al. (2009) Scotland	N=4 Distance: 157.7 km	Ultra-marathon trail running can predispose a runner to exercise induced hyponatremia
Easthope et al. (2010) France	N=23 (38.2 years) Disatnce:55 km	Ultra-marathon trail running produces muscle damage characterised by post-race inflammatory markers
Jouffrey et al. (2011) France	N=28 (43.0 years) Distance: 80 km	Ultra-marathon trail running does produce systolic and diastolic dysfunction which jeopardises cardiac function
Khodaee et al. (2011) USA	N=646 (41.0 years) Distance: 160.9 km	35% of runners visited the medical stations during the race complaining of musculoskeletal injuries, gastrointestinal and respiratory illnesses. Ankle sprains and plantar fasciitis were attributed to poor shoe stability and cushioning
Krabak et al. (2011) USA	N=369 Distance: 250 km	85% injury and illness prevailed among the runners. Runners should be educated on proper acclimation to trail races
Morin et al. (2011) France	N=18 (39.1 years) Distance: 166 km	The biomechanics of ultra-marathon trail running, especially during the braking phase elicit pain during downhill
Scheer and Murray (2011) Spain	N=69 (46.0 years) Distance: 219 km	The majority of runners sustained injury (56.5%) with a high prevalence of foot blisters (33.3%), musculoskeletal injuries (22.2%) and chafing (9.1%). The knee was the most common musculoskeletal injury
Denissen et al. (2012) South Africa	N=21 (39.3 years) Distance: 95 km	Continuous trail ultra-marathon running produces muscle damage identified by inflammatory markers
Kasmer et al. 2016 USA	N=165 Distance: 50 km	The unique predominant rear foot striking pattern of trail runners increases lower limb, ankle and foot injury
Saugy et al. (2013) Italy	N=15 (45.4 years) Distance: 330 km	Trail running produces neuromuscular fatigue and muscle damage which serves reduced running pace
Vitiello et al. (2013) Italy	N=21 (40.0 years) Distance:166 km	Ultra-marathon trail running does produce cardiac structural and functional changes that adversely affect the health status of runners
Degache et al. (2014) Italy	N=18 experimental (44.0 years) N=8 control (29.3 years) Distance: 330 km	Runners experience a greater neuromuscular challenge to stabilize their body towards the end of a trail ultra-marathon due to increased fatigue that predisposes them to injury.
Robach et al. (2014) France	N=22 (40.0 years) Distance: 166 km	Ultra-marathon trail running produces exercise induced anaemia which adversely impacts the red blood cell volume.
Cope and Kropelnicki (2015) United Kingdom	N=1 (44.0 years) Distance: 78.02 km	Ultra-marathon trail running in sub-zero temperature and high wind velocity caused transient freezing and subsequent abrasion of the cornea.
Sposta et al. (2015) Italy	N=46 (45.0 years) Distance: 330 km	Ultra-marathon trail running produces oxidative stress causing renal dysfunction and inflammation.
Vernillo et al. (2015)a Italy	N=29 (46.0 years) Distance: 65 km	Trail running declines pulmonary function due to the high ventilation and harsh environment, which impacts on the health status of the runner.
Vernillo et al. (2015)b Italy	N=14 (43.6 years) Distance: 65 km	Mountain ultra-marathon running induced fatigue increasing energy cost and reduced neuromuscular co-ordination.
Malliaropoulos et al. (2015) Greece	N=40 (39.4 years) >42.2 km	90% of the cohort sustained musculoskeletal injury, with lower back (42.5%) and knee (40%) injuries being most prevalent.
Boey et al. (2016) Belgium	N=35 (23.3 years)	Trail-running surface reduces running pace, which serves to protect the tibia from injury as compared to road surfaces.
Hambleton et al. (2016) USA	N=18 (25.0 years) Distance 50 km	Ultra-marathon trail running does produce muscle damage as indicated by salivary inflammatory biomarkers.
Hespanhol et al. (2016) Netherlands	N=228 >42.2 km	There was a 22% prevalence of trail-running injuries with the most susceptible anatomical sites being Achilles tendon, calf, knee and ankle.
Vernillo et al. (2016) Italy	N=77 Distance: 65 km	Medical illnesses (50.3%) were most prominent followed by musculoskeletal injuries (32.8%) and dermatological disorders (16.9%).

well-being and race performance of the runners. It is postulated that non-identification of AMS and HACE is probably due to the slow ascend up mountainous footpath and/or the gradual elevations of the races did warrant the onset of these illnesses. It is recommended that race convenors identify altitude sickness and remedies to combat these sicknesses when advertising their races. Further a pre-race educational meeting to all runners should be hosted to brief runners on all medical stations and procedures and preventative strategies against the onset of AMS, HACE and HAPE.

Practical consideration that ultra-marathon trail runners and race organizers need to deliberate:

i. Use of trail running shoes to enhance ankle stability

ii. Use of hiking poles to enhance runner's balance during their ascent and descent on rough terrain

iii. Prophylactic tapes to enhance joint stability and reduce acute musculoskeletal injuries

iv. Complete adequate training on trail paths, with trail running gear

v. Maintain a steady pace during the race to prevent muscle cramps, fatigue and high altitude sicknesses

vi. Use dry clothing to reduce the risk of fungal infection

vii. Adequately rehydrate before, during and after the race to prevent dehydration and other maladies

viii. Runners must be made aware of refreshment and medical stations on the designated route

ix. Medical staff must be well equipment to treat all injuries and illnesses

x. Create an evacuation planned route to the nearest hospital in the case of an emergency

Conclusion

Ultra-marathon trail running does produce significant injuries and illnesses, which warrants medical concern. Injury and illness rates vary from 18.9-1885.7/1000 runners, which is considerably higher than in ultra-marathon road running. The most vulnerable anatomical sites of musculoskeletal injury are the foot, ankle and knee. Common dermatological injuries include foot blisters, subungual hematoma, chafing and lacerations. Medical illnesses vary from muscle damage, fatigue, cramps and cardiorespiratory dysfunction.

The number of empirical research of ultra-marathon trail is considerably lower than that of road running. It is recommended that more research be conducted, to provide runners, coaches, sport scientists and medical practitioners a more accurate picture of the various injuries and illnesses. Most of the research on ultra-marathon trail-running injuries and illnesses has been predominantly conducted among the European countries (Italy, France and Greece). A single South African study documented ultra-marathon running injuries and illnesses, which also serves as the only publication in the African continent (Denissen et al*.,* 2012). It is strongly recommended that more vigorous research be conducted among the South Africa ultra-marathon trail runners.

Upon reflection of the research conducted between the periods of 2007-2016 the authors concur with comments of Herzog (2016) and Hulme and Finch (2016) who identify the following criticism. The absence of endurance runners as active participants in the research but rather were treated as passive subjects who were measured and tested like one would test laboratory rats (Herzog, 2016). It is strongly recommended that the runners become active participants in the research helping to identify why they get injured and what maybe the underlying mechanism of injury. Epidemiological surveillances should incorporate a qualitative and quantitative design to extract valuable information about the runners and their mechanisms of injury and illnesses.

CONFLICT OF INTERESTS

The authors declare that they have no conflict of interest.

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