Psychology of Sport & Exercise 37 (2018) 43–58

Contents lists available at ScienceDirect

Psychology of Sport & Exercise

journal homepage: www.elsevier.com/locate/psychsport

The psychology of ultra-marathon runners: A systematic review

Gregory S. Roebuck[a,*], Paul B. Fitzgerald[a], Donna M. Urquhart[b], Sin-Ki Ng[a], Flavia M. Cicuttini[b], Bernadette M. Fitzgibbon[a]

[a] *Monash Alfred Psychiatry Research Centre, Monash University Central Clinical School and The Alfred, Level 4, 607 St Kilda Road, Melbourne, Victoria, Australia*
[b] *Department of Epidemiology and Preventive Medicine, School of Public Health and Preventive Medicine, Monash University, The Alfred Centre, 99 Commercial Road, Melbourne, Victoria, Australia*

A R T I C L E I N F O

Keywords:
Ultra-runner
Ultra-endurance
Distance runner
Personality
Mood
Cognition

A B S T R A C T

Objectives: An 'ultra-marathon' is a footrace over a distance > 42.2 km. There is considerable interest in the psychological characteristics of ultra-marathon runners ('ultra-runners') and the psychological effects of running an ultra-marathon. This review aimed to summarise the existing literature concerning the psychology of ultra-runners.
Design: A systematic review was performed. Studies were included if they investigated ultra-runners' personality traits, mood, cognitive processes, cognitive function, pain perception, motivations, phenomenology, psychopathology or response to sports psychology interventions.
Method: Four databases (PubMed, Scopus, Web of Science and PsycINFO) were searched electronically up until December 2017.
Results: Fifty-one studies met the inclusion criteria. A few conclusions regarding the psychology of ultra-runners may be drawn from these studies. First, the acute mood effects of ultra-running appear to include an increase in fatigue and a decrease in vigour and tension. Secondly, the most important factor motivating ultra-runners to engage in their sport appears to be the opportunity to achieve personal goals. Finally, ultra-running seems to be associated with a psychological drive to explore physical and mental limits.
Conclusions: Although the existing literature sheds some light on ultra-runners' mood states, motivations and phenomenology, further high-quality studies investigating the psychology of these remarkable athletes are needed.

1. Introduction

An 'ultra-marathon' is a footrace over a distance longer than the marathon distance of 42.2 km (26.2 mi). Ultra-marathons can be distance-limited or time-limited. In a distance-limited race, the aim is to run a certain distance in the shortest time. Common distances for distance-limited ultra-marathons include 50 km (31.1 mi), 80.5 km (50 mi), 100 km (62.1 mi) and 161 km (100 mi). In a time-limited race, the aim is to run the longest distance within a given time. Common times for time-limited ultra-marathons include 6 h, 12 h, 24 h and 48 h. Some ultra-marathons involve multiple running stages held over consecutive days. The total distance run in these multi-stage races can be extremely long. In the world's longest ultra-marathon, the Self-Transcendence 3100 Mile Race, competitors run 4989 km (3100 mi) over a maximum of 52 days, which represents a minimum daily running distance of 95.9 km (59.6 mi), or over two marathons (http://3100.srichinmoyraces.org). Ultra-marathons can be run on any surface and are often held in remote wilderness settings. They fall within the broader category of 'ultra-endurance' events. These are most commonly defined as endurance events with a duration of more than 6 h (Wortley & Islas, 2011), although this definition actually excludes some of the shorter ultra-marathons, such as 50-km races, which are normally completed in under 6 h.

Since ultra-marathon running (or 'ultra-running') became an organised sport in the 1970s and 1980s, there has been considerable interest in the psychological effects of ultra-running and the psychological characteristics of ultra-runners. Much of this interest stems from the unique demands that ultra-running and other ultra-endurance sports place on participants. Ultra-runners must sustain endurance exercise for extremely long periods of time. The psychological effects of such prolonged endurance exercise and the psychological attributes of the athletes who successfully engage in it are of obvious interest to sport psychologists and exercise scientists. Questions that have been

* Corresponding author.
E-mail addresses: gregory.scott.roebuck@monash.edu (G.S. Roebuck), paul.fitzgerald@monash.edu (P.B. Fitzgerald), donna.urquhart@monash.edu (D.M. Urquhart), sinki.ng@monash.edu (S.-K. Ng), flavia.cicuttini@monash.edu (F.M. Cicuttini), bernadette.fitzgibbon@monash.edu (B.M. Fitzgibbon).

https://doi.org/10.1016/j.psychsport.2018.04.004
Received 2 May 2017; Received in revised form 10 April 2018; Accepted 12 April 2018
Available online 18 April 2018
1469-0292/

investigated by researchers include what motivates ultra-runners to engage in such an arduous sport (Doppelmayr & Molkenthin, 2004; Hanson, Madaras, Dicke, & Buckworth, 2015; Hashimoto, Hagura, Kuriyama, & Nishiyamai, 2006; Krouse, Ransdell, Lucas, & Pritchard, 2011), whether ultra-running is associated with any personality traits (Folkins & Wieselberg-Bell, 1981; Freund et al., 2013; Hughes, Case, Stuempfle, & Evans, 2003; McCutcheon & Yoakum, 1983), what effects running an ultra-marathon has on mood and cognitive function (Doppelmayr, Finkernagel, & Doppelmayr, 2005; Graham et al., 2012; Hurdiel et al., 2015; Lucas, Anson, Palmer, Hellemans, & Cotter, 2009; Tharion, McMenemy, Terry, & Rauch, 1990; Tharion, Strowman, & Rauch, 1988; Wollseiffen et al., 2016), whether ultra-runners have abnormal pain tolerance (Freund et al., 2013) and whether ultra-running is associated with psychopathologies such as eating disorders and exercise dependence (Allegre, Therme, & Griffiths, 2007; Lantz, Rhea, & Mesnier, 2004; Pierce, McGowan, & Lynn, 1993; Szabo, De La Vega, Ruiz-Barquin, & Rivera, 2013).

Although there is a significant scientific literature investigating the psychology of ultra-runners, no attempt has yet been made to synthesise the findings from individual studies and to draw some general conclusions regarding these unique athletes. Indeed, no published review of this literature exists. The aim of this review is to provide a critical summary of the literature, to indicate what is currently known about ultra-runners' psychology and to highlight gaps in the literature and directions for future research.

2. Methods

2.1. Protocol and eligibility criteria

A systematic review was conducted in accordance with the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) guidelines (Liberati et al., 2009). The methods used in the review were specified in advance and documented in a protocol, which is available online as part of the supplementary electronic materials. Studies were included in the review if they were reported in a peer-reviewed journal article written in English and had as one of their main purposes the investigation of ultra-runners' (i) personality traits, (ii) mood or emotions, (iii) cognitive processes during races, (iv) cognitive function, (v) pain perception, (vi) motivations for engaging in ultra-running, (vii) phenomenology or subjective experience of ultra-running, (viii) psychopathological traits or symptoms or (ix) response to sports psychology interventions. With respect to pain perception, studies that involved the measurement of pain-related psychophysiological parameters such as pain threshold or pain tolerance were included in the review. Studies that investigated only the experience of muscle pain by ultra-runners during or after races were not included, however (see, e.g., Nieman et al., 2005). Studies that investigated the experience of thermal sensations, nausea or perceived exertion by ultra-runners during or after races were also treated as not falling within the inclusion criteria (see, e.g., Brown & Connolly, 2015; Clemente-Suárez, 2015; Joslin et al., 2014; Stuempfle & Hoffman, 2015). An 'ultra-runner' was defined as a person who, at the time of the study, had previously completed or was registered to compete in an event that involved running more than 42.2 km (26.2 mi). This definition included competitors in 'walk/run' events, which are races in which participants are permitted to either walk or run.

2.2. Information sources and search strategy

Relevant articles were identified by electronically searching the PubMed, Scopus, Web of Science and PsycINFO databases. The databases were searched on 1 December 2017 using the following search string (appropriately adapted for each database): ultra-marathon OR ultramarathon OR "ultra marathon" OR ultra-runner OR ultrarunner OR "ultra runner" OR ultra-distance OR ultradistance OR "ultra distance" OR ultra-endurance OR ultraendurance OR "ultra endurance" OR ultra-marathoner OR ultramarathoner OR "ultra marathoner" OR ultra-marathons OR ultramarathons OR "ultra marathons" OR ultra-runners OR ultrarunners OR "ultra runners" OR ultra-marathoners OR ultramarathoners OR "ultra marathoners". In PubMed and Web of Science, all search fields were searched. In Scopus and PsycINFO, the 'Title', 'Abstract' and 'Keywords' or 'Key Concepts' search fields were searched. There was no restriction in the searches on publication date or document type. Eligibility assessment was performed in an unblinded, standardised manner by two reviewers (GR and SN) acting independently. The reviewers reviewed the title and abstract of each search record to assess whether the record was potentially eligible for inclusion in the review. They then reviewed the full-text of any article that was deemed to be potentially eligible for inclusion and determined whether the article met the inclusion criteria. Disagreements between the reviewers were resolved by their meeting to discuss the article and reaching a consensus as to its inclusion or exclusion.

3. Results

3.1. Study selection

The searches produced a total of 3444 records. After removal of duplicates, there were 1506 unique records. Of these, 1384 were discarded following review of their title and abstract. The full-text of the remaining 122 articles was reviewed in detail and it was determined that 42 of these articles met the inclusion criteria. A further nine articles that met the inclusion criteria were identified by checking the references of these articles and checking their forward citations on Google Scholar. Thus, 51 articles, and the studies reported by these articles, were included in the review. A flowchart summarising the study selection process is depicted in Fig. 1.

3.2. Study characteristics

For each of the included studies, the study population, methods and relevant findings are summarised in Table 1. The studies are divided into 10 sub-categories in Table 1. Nine of these sub-categories correspond to the nine areas of research identified in the inclusion criteria. The final sub-category contains studies that fell within one of these areas of research but were 'case studies' in the sense that they involved only a single participant. The number of studies in each of the sub-categories is as follows: (i) ultra-runners' personality traits — 9 studies, (ii) ultra-runners' mood or emotions — 11 studies, (iii) ultra-runners' cognitive processes during races — 1 study, (iv) ultra-runners' cognitive function — 9 studies, (v) ultra-runners' pain perception — 2 studies, (vi) ultra-runners' motivations for engaging in ultra-running — 6 studies, (vii) ultra-runners' phenomenology — 7 studies, (viii) ultra-runners' psychopathological traits or symptoms — 7 studies, (ix) ultra-runners' response to sports psychology interventions — 1 study and (x) case studies — 5 studies. Seven studies fell within more than one sub-category — these are marked with an asterisk (*) in Table 1. As Table 1 shows, the studies included in the review are methodologically very diverse. Thirty-nine of the studies are quantitative studies, eight are qualitative studies and four employ a mix of quantitative and qualitative methods. The quantitative studies include cross-sectional studies, uncontrolled pretest-posttest studies (where the relevant 'intervention' is running an ultra-marathon), controlled pretest-posttest studies and interrupted time series studies. Because of this methodological diversity and the impossibility of using a single quality assessment tool or even a small number of such tools to assess the methodological quality of all of the included studies, a risk of bias assessment was not performed as part of this systematic review.

3.2.1. Ultra-runners' personality traits

Nine studies investigated the personality traits possessed by ultra-

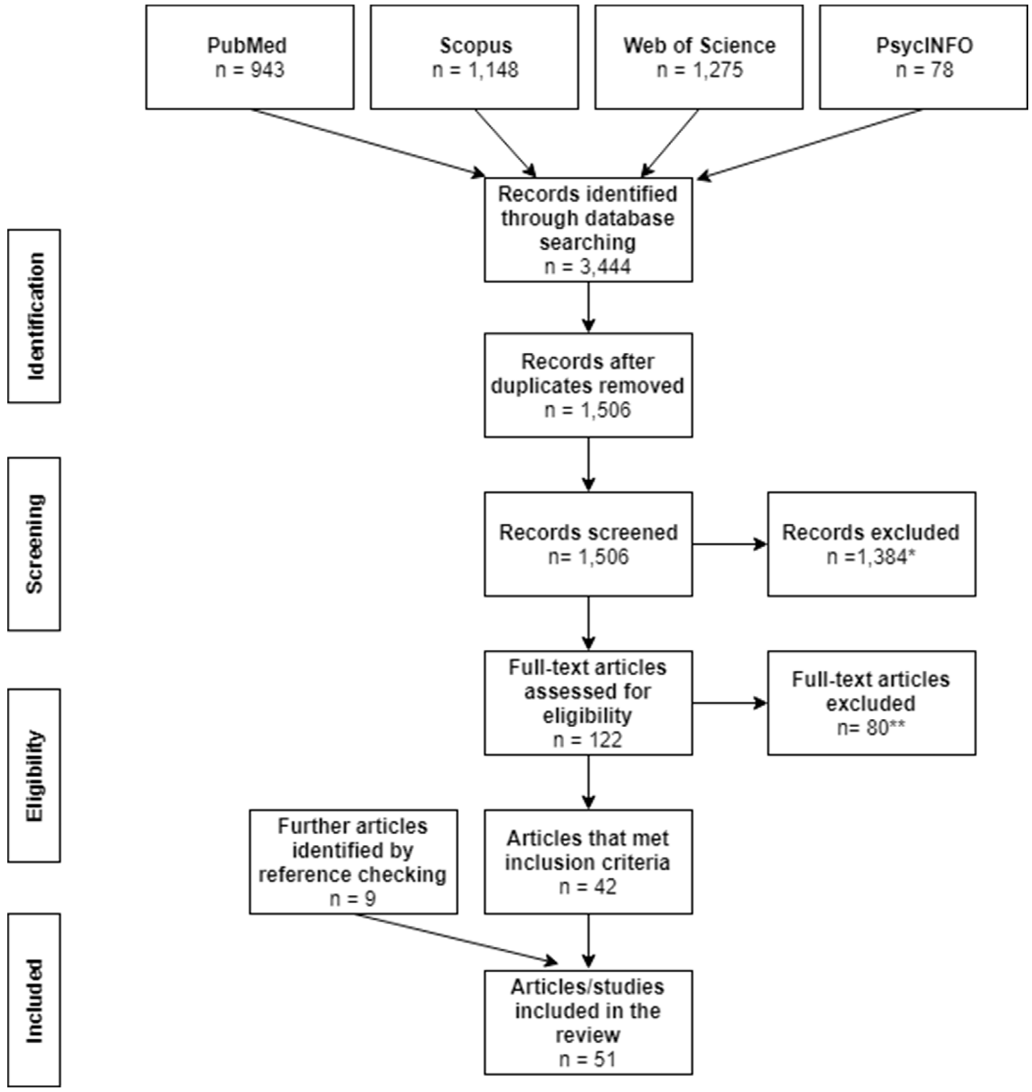

Fig. 1. Flowchart showing study selection process.
*Reason for exclusion: conference abstract (n = 102); book chapter/article in non-peer-reviewed journal/PhD thesis (n = 40); not in English (n = 33); correction/reply (n = 12); not relevant (n = 1,197).*Reason for exclusion: review article (n = 13); subjects not ultra-runners (n = 13); non-scientific article/study (n = 5); not relevant (n = 49).

runners (Acevedo, Dzewaltowski, Gill, & Noble, 1992; Folkins & Wieselberg-Bell, 1981; Freund et al., 2013; Hashimoto et al., 2006; Hughes, Case, Stuempfle, Evans, & Personality profiles of Iditasport ultra-marathon participants, 2003; Krouse et al., 2011; McCutcheon & Yoakum, 1983; Rauch, Tharion, Strowman, & Shukitt, 1988; Teranishi Martinez & Scott, 2016). These studies used a wide range of psychometric instruments, including the Adjective Checklist, Multiple Affect Adjective Checklist (MAACL), Philosophies of Human Nature Scale, Self-Motivation Inventory, State-Trait Anxiety Inventory, Commitment to Running Scale (CRS), Sport Orientation Questionnaire (SOQ), Trait Sport-Confidence Inventory (TSCI), NEO-Five Factor Inventory, Sensation Seeking Scale (SSS), Myers-Briggs Type Indicator, Perception of Success Questionnaire, Temperament and Character Inventory, General Self-Efficacy Scale and Ten-Item Personality Inventory. Seven studies found that ultra-running was associated with certain personality traits. Compared with the general population, ultra-runners have been reported to be more self-motivated (Rauch et al., 1988), more extraverted, open and experience-seeking and less disinhibited (Hughes et al., 2003), more introverted (Hashimoto et al., 2006) and more self-transcendent and less cooperative and reward-dependent (Freund et al., 2013). Compared with other runners, they have been reported to be more neurotic (Teranishi Martinez & Scott, 2016). Acevedo et al. (1992) compared a sample of ultra-runners to the norm groups for the SOQ, TSCI and CRS, which consisted of a population of undergraduate students enrolled in non-competitive physical activity skills classes (Gill & Deeter, 1988), a population of high school, university and professional athletes from various sports (Vealey, 1986) and a population of runners of varying levels of experience and ability (Carmack & Martens, 1979), respectively. Compared with these norm groups, ultra-runners were more competitive and goal-oriented but less win-oriented, more confident and more committed to running. Krouse et al. (2011) examined the goal orientations of a cohort of female ultra-runners and found that they were considerably higher in task orientation than ego orientation (with respect to ultra-running). The remaining two studies in this sub-category did not find any significant differences between ultra-runners and the general population with respect to personality traits (Folkins & Wieselberg-Bell, 1981; McCutcheon & Yoakum, 1983).

3.2.2. Ultra-runners' mood or emotions

Eleven studies investigated ultra-runners' mood states or emotions (Anglem, Lucas, Rose, & Cotter, 2008; Graham et al., 2012; Hoffman & Hoffman, 2008; Lane & Wilson, 2011; Micklewright et al., 2009;

Table 1
Summary of the study populations, methods and relevant findings of the included studies.

Study	Population	Methods	Relevant findings
i. Ultra-runners' personality traits			
Folkins & Wieselberg-Bell, 1981*	46 competitors in a 161-km (100-mi) UM (4 ♀, 42 ♂)	Participants completed the ACL and MAACL.	● The mean scores on both instruments were within the normal range.
McCutcheon & Yoakum, 1983	50 URs, 8 DRs and 58 HCs (all ♂)	Participants completed the SMI and four subscales of the PHNS.	● There were no significant differences between the three groups on either instrument. ● There were also no differences between faster and slower runners in the UR group.
Rauch et al., 1988*	44 competitors in an 80.5-km (50-mi) UM (2 ♀, 42 ♂)	Participants completed the SMI and Form X-2 of the STAI.	● Participants' SMI scores were higher than those reported for a norm group of undergraduate college students but similar to those reported for other athletes. ● SMI and STAI scores were not predictive of finishing status.
Acevedo et al., 1992*	112 competitors in one of two 161-km (100-mi) UMs (26 ♀, 86 ♂)	Participants completed the SOQ, TSCI and CRS and a questionnaire assessing their goals.	● Participants were more competitive, goal-oriented, confident and committed to running than other athletes. ● They were less win-oriented than other athletes. ● Goals related to finishing time were rated as very important. ● Goals related to place were rated as less important. ● Scores on the SOQ, TSCI and CRS were not predictive of finishing status.
Hughes et al., 2003	66 competitors in a 161-km (100-mi) multi-disciplinary race over 3 years (18 ♀, 48 ♂), including 35 URs	Participants completed Form S of the NEO-FFI and Form V of the SSS.	● Participants were more extraverted and open than the norm group for the NEO-FFI. ● They were more experience-seeking but less disinhibited than the norm group for the SSS.
Hashimoto et al., 2006*	52 competitors in either a 100-km (62.1-mi) UM or a 24-h UM (12 ♀, 40 ♂)	Participants completed the Japanese version of the MBTI.	● The ISFJ type was the most common personality type among participants. ● The ISFJ and INFJ types and introversion were all significantly more common among participants than in the normative population for the Japanese version of the MBTI.
Krouse et al., 2011*	344 URs (all ♀)	Participants completed the PSQ.	● Participants were higher in task orientation than ego orientation.
Freund et al., 2013*	22 participants: 11 competitors in a 64-day, 4487-km (2788-mi) UM and 11 matched HCs (all ♂)	Participants completed the German versions of the TCI and GSES.	● The URs were less cooperative and reward dependent and more self-transcendent than the HCs on the TCI. ● There were no significant differences between the two groups on the GSES.
Teranishi Martinez & Scott, 2016	189 participants (132 ♀, 57 ♂): 68 URs, 38 MRs, 62 DRs (5 km to HM), 17 DRs (< 5 km), 2 non-runners and 2 other participants	Participants completed the TIPI, FFS, a measure of well-being and a questionnaire assessing the frequency with which they ran in natural and non-natural environments.	● The URs were more neurotic, experienced greater flow and spent more time running in natural environments than the non-URs. ● There was no difference between the URs and non-URs regarding well-being levels.
ii. Ultra-runners' mood or emotions			
Rauch et al., 1988*	44 competitors in an 80.5-km (50-mi) UM (2 ♀, 42 ♂)	Participants completed the POMS before and after the race.	● Participants exhibited the 'iceberg' profile of mood states before the race. ● Fatigue increased and vigour and tension decreased during the race.
Tharion et al., 1988	56 competitors in either an 80.5-km (50-mi) UM or a 161-km (100-mi) UM (all ♂)	Participants completed the POMS before and after the races.	● Participants exhibited the 'iceberg' profile of mood states before the race. ● Fatigue, confusion and depression increased and vigour and tension decreased during the race. ● The only significant difference between finishers and non-finishers was that finishers were more fatigued than non-finishers after the race.

(*continued on next page*)

Table 1 (*continued*)

Study	Population	Methods	Relevant findings
Tharion et al., 1990	14 competitors in a 161-km (100-mi) UM (all ♂)	Participants completed the POMS before, immediately after and 1 week, 1 month and 3 months after the race.	● Fatigue increased during the race but returned to pre-race levels by 1 week after the race. ● Vigour decreased during the race and returned to pre-race levels by 1 week to 1 month after the race. ● Tension was higher pre-race than at any time after the race.
Anglem et al., 2008	60 competitors in a 411-km (255-mi), 5-day multi-disciplinary adventure race (19 ♀, 41 ♂)	Participants completed the BRUMS daily during the race and serially in the fortnight following the race.	● Fatigue increased and vigour and tension decreased during the race. All three scales returned to baseline by 2 weeks after the race. ● Depression, anger and confusion were generally low but depression was modestly elevated on the third day after the race.
Hoffman & Hoffman, 2008	48 participants (24 ♀, 24 ♂): 16 URs, 16 regular moderate exercisers and 16 non-exercisers	Participants completed the POMS before and after a short session of aerobic exercise.	● TMD decreased significantly for all three groups. ● The size of the effect was approximately double for the URs and regular moderate exercisers compared with the non-exercisers, however.
Micklewright et al., 2009	8 competitors in a 73.4-km (45.6-mi) UM (1 ♀, 7 ♂)	Participants completed a shortened version of the POMS before and immediately after the race.	● Fatigue and confusion increased and vigour decreased during the race. ● Confusion was elevated above baseline immediately before the race. ● Post-race TMD, confusion and vigour were related to the discrepancy between a runner's predicted finishing time and their actual finishing time.
Lane & Wilson, 2011	34 competitors in a 282-km (175-mi), 6-day UM (8 ♀, 24 ♂)	Participants completed the EmIS and BRUMS before the race and also completed the BRUMS and items from the UMACL before and after each stage of the race.	● Fatigue increased and vigour decreased during each stage of the race except the final stage. ● High trait emotional intelligence was associated with higher calmness and happiness and lower anger, confusion, depression, fatigue and tension during the race.
Nicolas et al., 2011	14 competitors in a 24-h UM (all ♂)	Participants completed the French version of the RESTQ-Sport immediately before and after the race and serially in the month following the race.	● Total Stress increased during the race and then decreased after the race, with the decrease reaching significance on day 6 after the race. ● Total Recovery decreased during the race, reached its lowest point on day 3 after the race and had returned to pre-race levels by day 15.
Graham et al., 2012	11 competitors in a 7-day, 241-km (150-mi) UM (all ♂)	Participants completed the BRUMS each day during the race.	● Fatigue increased and vigour decreased over the first 6 days of the race. ● Both improved on the final day of the race but not to pre-race levels. ● Depression, tension and confusion increased over the first 6 days but returned to pre-race levels on the final day.
Wollseiffen et al., 2016*	11 URs (5 ♀, 6 ♂)	Participants completed a 6-h running session, with EEG performed and mood assessed using the MoodMeter® computer program and flow state assessed using the FFS-2 before the session and hourly during the session.	● Perceived psychological relaxation and flow state were elevated after 1 h but then decreased over the following 5 h. ● Perceived physical state and motivational state were stable during the first hour but then decreased over the following 5 h. ● Beta activity in the frontal cortex decreased after 1 h and remained at that decreased level over the following 5 h.
Longman et al., 2017	66 competitors in a 165.1-km (102.6-mi) UM (all ♂ and all heterosexual)	Participants reported valence and arousal ratings in response to sexually provocative images and positive- and negative-valence IAPS images before and after the race.	● Arousal ratings in response to sexually provocative images were significantly decreased after the race. ● There was no change in valence or arousal ratings for the IAPS images.

(*continued on next page*)

Table 1 (*continued*)

Study	Population	Methods	Relevant findings
iii. Ultra-runners' cognitive processes during races			
Acevedo et al., 1992*	112 competitors in one of two 161-km (100-mi) UMs (26 ♀, 86 ♂)	Participants completed a questionnaire assessing their cognitive processes during races and cognitive strategies during training and racing.	● In response to a forced-choice question, about 50% of participants reported experiencing mainly internally focused thoughts during races and 50% reported experiencing mainly externally focussed thoughts. ● In response to an open question, however, approximately 75% of the thoughts described were externally focussed. ● A variety of cognitive strategies were used during training and racing, including visualisation, reading pre-race paraphernalia, setting goals, self-talk and thought control.
iv. Ultra-runners' cognitive function			
Glace et al., 2002	19 competitors in a 161-km (100-mi) UM (1 ♀, 18 ♂)	Participants were monitored during the race for MSC and their dietary intake before and during the race was also monitored.	● 10 participants reported MSC, which included light-headedness and confusion. ● Participants who developed MSC had a greater intake of total calories, carbohydrates and fluid during the race than those who did not and also completed shorter training runs.
Doppelmayr et al., 2005	2 competitors in a 216-km (134-mi) UM (both ♂)	Participants performed tests of cognitive performance before the race and then at regular intervals during the race.	● Cognitive performance decreased over the course of the race but not in a linear fashion. ● It decreased over the course of day 1, then increased and peaked at a level above baseline on the morning of day 2, decreased again over the course of day 2, reached its lowest level on the morning of day 3 and then increased in the last testing session.
Lucas et al., 2009	9 competitors in a 411-km (255-mi), 5-day, multi-disciplinary adventure race	Participants were administered the Stroop test before, during and after the race, with some testing occurring while they performed a cycling stress test at various intensities.	● Response time and error rate for simple tasks were stable across the race. ● Response time for complex tasks was 16% higher after the race but the change was not significant. ● Error rate for complex tasks was stable across the race. ● Response time for complex tasks improved as participants exercised at higher intensities.
Hurdiel et al., 2015	17 competitors in a 168-km (104-mi) UM (1 ♀, 16 ♂)	Participants completed a test of cognitive performance before and after the race and their sleep duration during the race was measured.	● Cognitive performance was significantly reduced after the race. ● Mean (± SD) sleep duration during the race was 12 (± 17) minutes. ● There was no correlation between post-race cognitive performance and sleep duration or finishing time.
Cona et al., 2015	30 competitors in an 80-km (49.7-mi) UM (all ♂)	Participants performed two tasks assessing cognitive performance before the race: an inhibitory control task and a dual-task paradigm incorporating a working memory task and a prospective memory task.	● Faster runners in the race outperformed slower runners in various ways. ● They were more accurate on the inhibitory control task in trials requiring motor inhibition. ● They also had shorter response times in the dual-task paradigm in trials where a prospective memory cue with a positive or negative emotional valence was given.
Wollseiffen et al., 2016*	11 URs (5 ♀, 6 ♂)	Participants completed a 6-h running session and their cognitive performance was assessed using an adapted version of the 'Chalkboard Challenge' brain game before the session and hourly during the session.	● Cognitive performance was stable across the whole 6 h.
Tonacci et al., 2016	149 participants (23 ♀, 126 ♂): 53 competitors in a 332.5-km (206.6-mi) mountain UM, 43 non-UR athletes and 53 HCs	The UR participants' olfactory function was measured before, during and after the race and the olfactory function of the non-UR athletes and HCs was measured at rest.	● The UR participants' olfactory function decreased significantly from pre-race to post-race. ● Mid-race olfactory function was weakly correlated with mid-race total body water and post-race olfactory function was correlated with sleep duration during the race. ● The UR participants' pre-race olfactory function was similar to that of the non-UR athletes and HCs.

(*continued on next page*)

Table 1 (*continued*)

Study	Population	Methods	Relevant findings
Martínez-Navarro et al., 2016	50 competitors in a 118-km (73-mi) UM (6 ♀, 44 ♂)	Participants' executive function was assessed using the colour-word interference task of the Stroop test before and after the race.	● Executive function did not significantly change across the race. ● Pre-race executive function and the change in executive function were not correlated with finishing time. ● The change in executive function was positively correlated with participants' heart rate responses to an orthostatic challenge post-race.
Alessandro Tonacci et al., 2017	40 competitors in a 16-day, 866-km (538-mi) UM (4 ♀, 36 ♂)	Participants had their olfactory function tested and completed a shortened version of the COWAT and the TMT before, during and after the race.	● Olfactory function decreased significantly over the course of the race. ● Total sleep duration was positively correlated with the change in olfactory function. ● COWAT scores increased from pre-race to post-race. ● TMT scores did not significantly change from pre-race to post-race.
v. Ultra-runners' pain perception			
Hoffman et al., 2007	32 participants: 21 competitors in a 161-km (100-mi) UM (5 ♀, 16 ♂) and 11 HCs (6 ♂, 5 ♀)	Participants underwent a test of pressure pain sensitivity and provided a rating of overall pain level before and immediately after the race.	● Faster runners (but not slower runners) experienced a modest reduction in pressure pain sensitivity after the race. ● There was no relationship between pain pressure sensitivity and overall pain level after the race.
Freund et al., 2013*	22 participants: 11 competitors in a 64-day, 4487-km (2788-mi) UM and 11 matched HCs (all ♂)	Participants' cold pain tolerance was measured using the CPT and they also completed the German versions of the TCI and GSES.	● The URs displayed higher pain tolerance than the HCs on the CPT. ● Mean (± SD) immersion time was 180 s (± 0 s) for the URs compared to 96 s (± 58 s) for the HCs. ● Pain intensity rating at 180 s was correlated with scores on various TCI scales, including the dependence and pure-hearted conscience scales.
vi. Ultra-runners' motivations for engaging in ultra-running			
Doppelmayr & Molkenthin, 2004	149 DRs (all ♂): 60 URs, 54 competitors in a 230-km (143-mi) desert adventure UM and 35 MRs	Participants reported their reasons for participating in their respective events and these were assigned to one or more of the MOMS subscales and 4 additional categories of motivations.	● 'Nature', 'personal goal achievement' and 'life meaning' were the most commonly cited motivations for the adventure URs. ● 'Personal goal achievement', 'nature' and 'self-esteem' were the most commonly cited motivations for the non-adventure URs. ● 'Competition' was more commonly cited by the MRs than the other two groups.
Hashimoto et al., 2006*	52 competitors in either a 100-km (62.1-mi) UM or a 24-h UM (12 ♀, 40 ♂)	Participants completed a questionnaire based on the MOMS asking them their reasons for beginning and for continuing ultra-running.	● 'To feel sense of achievement', 'to provide challenge', 'to push beyond current capability', 'to socialise with other runners' and 'to meet people' were the most commonly cited motivations for continuing ultra-running.
Krouse et al., 2011*	344 URs (all ♀)	Participants completed the MOMS.	● 'Personal goal achievement', 'general health orientation' and 'self-esteem' were the most important motivations. ● 'Competition' was the least important.
Kruger & Saayman, 2013	437 competitors in an 89-km (55.3-mi) UM	Participants completed a questionnaire assessing their motivations for participating in the race.	● 'Intrinsic achievement' and 'commitment' were the most important motivational factors. ● 'Exploration and competitiveness' was the least important.
Hanson et al., 2015	865 DRs: 355 URs (67% ♂), 315 MRs (47% ♂) and 195 HMRs (32% ♂)	Participants completed the MOMS.	● 'Personal goal achievement', 'general health orientation' and 'self-esteem' were the most important motivations for the URs. ● 'Recognition' and 'competition' were the least important for them. ● 'Life meaning' was more important and 'weight concern' and 'general health orientation' less important for the URs compared to the other groups.

(*continued on next page*)

Table 1 (*continued*)

Study	Population	Methods	Relevant findings
Ferrer et al., 2015	9 competitors in either a 24-h or a 48-h UM (4 ♀, 5 ♂)	Participants completed the MOMS.	● 'General health orientation' and 'personal goal achievement' were the most important motivations. ● Age was positively associated with physical motivations. ● Physical motivations were negatively associated with mean running speed but positively associated with total distance covered during the 24-h race.
vii. Ultra-runners' phenomenology			
Hanold, 2010	8 elite URs (all ♀)	Semi-structured interviews were conducted with participants.	● Participants expressed the view that no single ideal ultra-running body exists. ● Ultra-running assisted some participants to view their bodies more positively. ● Participants distinguished between two types of pain: 'good pain' and 'bad pain'.
Crust et al., 2010	12 participants in a 100-km (62.1-mi) walk/run event (7 ♀, 5 ♂)	Participants were interviewed several times during the event and finishers subsequently participated in a focus group.	● Participants identified the ability to maintain a sense of perspective, tenacity, total commitment to one's goals, challenge-seeking, a sense of humour and objectivity as attributes of the mentally tough event participant.
Holt et al., 2014	6 competitors in a 125-km (77.7-mi) UM (1 ♀, 5 ♂)	Participants were interviewed before and during the race and wrote a summary of their experiences and participated in a focus group after the race.	● Participants encountered numerous stressors during the race. ● Coping strategies included making small goals, treating the race as a mental or physical battle, careful monitoring of pace, nutrition and hydration and seeking social support. ● Non-finishers were generally dejected after the race while finishers described it as a major life experience.
Simpson et al., 2014	26 URs (7 ♀, 19 ♂)	Phenomenological interviews were conducted with participants.	● There were five themes that characterised participants' experiences of participating in UMs: community, preparation and strategy, management, discovery and personal achievement.
Jaeschke et al., 2016	12 URs (3 ♀, 9 ♂)	Semi-structured interviews were conducted with participants.	● Themes relating to mental toughness that emerged from participants' responses included perseverance/persistence, overcoming adversity, perspective, life experience, psychological skills use and camaraderie in the ultra-running community.
Philippe et al., 2016	10 competitors in either a 65-km (40-mi), 97-km (60-mi) or 173-km (107-mi) UM (2 ♀, 8 ♂) who withdrew from their respective races	Self-confrontation interviews were conducted with participants after their races.	● Seven sequences of experience were representative of participants' experiences: (1) feeling pain; (2) putting meaning to those feelings; (3) adjusting running style; (4) attempting to overcome the problem; (5) other runners' influences; (6) assessing the situation; and (7) deciding to withdraw.
Rochat et al., 2017	13 competitors in either a 65-km (40-mi), 97-km (60-mi) or 173-km (107-mi) UM (4 ♀, 9 ♂) ('EI participants') and 28 competitors in various UMs ranging in length from 50 km (31 mi) to 170 km (106 mi) ('blog participants')	EIs were conducted with the EI participants after their races and blog posts by the blog participants about their races were obtained and the two sets of data were combined and analysed, with participants' sequences of experience during the races categorised into one of three 'vitality states': SVP, SVL or SVR.	● Finishers had more sequences in SVP and fewer sequences in SVL compared with non-finishers. ● Finishers were also more likely to experience a transition from SVL to SVP than non-finishers. ● SVP was more common from the second quarter of the races onwards and SVL more common from the third quarter of the races onwards.
viii. Ultra-runners' psychopathological traits or symptoms			
Folkins & Wieselberg-Bell, 1981*	46 competitors in a 161-km (100-mi) UM (4 ♀, 42 ♂)	Participants completed the MMPI.	● Mean scores on all MMPI scales were within the normal range. ● Finishers had more deviant scores than non-finishers on various scales, however, including the psychopathic deviant, hysteria, schizophrenia and hypochondriasis scales. ● A weighted combination of MMPI scales predicted finishing status with 79% accuracy.

(*continued on next page*)

Table 1 (*continued*)

Study	Population	Methods	Relevant findings
Weight & Noakes, 1987	150 participants (all ♀): 15 URs, 85 MRs, 25 cross-country runners and 25 HCs	Participants completed the EAT-26 and EDI.	● 14% of runner participants had EAT-26 scores indicating at-risk status for an eating disorder but only 4% also reported a history of low body mass and amenorrhoea. ● 20% of the UR group were at risk of developing an eating disorder and had a history of low body mass and amenorrhoea. ● The UR group had higher EAT-26 scores than the other three groups. ● There were no significant differences between the groups on the EDI.
Pierce et al., 1993	150 DRs (all ♂): 61 URs, 32 MRs, 24 5-km runners and 33 recreational runners	Participants completed the NAS.	● The URs and MRs had higher NAS scores than the other two groups and the URs had higher scores than the MRs. ● NAS scores were positively correlated with average weekly training distance.
Lantz et al., 2004	87 competitors in either an 80.5-km (50-mi) UM or 161-km (100-mi) UM (14 ♀, 73 ♂)	Participants completed the EAT-26, ExIS and BAS.	● EAT-26 score was positively correlated with ExIS score and score on the injury tolerance scale of the BAS. ● ExIS score was positively correlated with score on the injury tolerance scale of the BAS. ● Female participants with high ExIS scores were more likely to report disordered eating behaviours than male participants and female participants with low or moderate ExIS scores.
Allegre et al., 2007	95 competitors in a 100-km (62.1-mi) UM (9 ♀, 86 ♂)	Participants completed the French version of the EDS-R and a questionnaire assessing their physical activity habits.	● 3.2% of participants were at risk for exercise dependence. ● The strongest positive predictor of EDS-R score was engaging in exercise in the city in an unstructured space and the strongest negative predictors were increasing age and BMI.
Szabo et al., 2013	242 participants (78 ♀, 164 ♂): 95 elite URs and 147 university athletes	Participants completed the Spanish version of the EAI.	● 17% of the URs and 8.8% of the university athletes were at risk for exercise addiction. ● Training volume was positively associated with EAI score for the university athletes but not the URs.
Folscher et al., 2015	306 competitors in an 89-km (55.3-mi) UM (all ♀)	Participants completed the LEAF-Q and FAST and a questionnaire assessing knowledge of the FAT.	● 32% of participants reported disordered eating behaviours and 5.2% met the criteria for a clinical eating disorder. ● 44.1% of participants were at risk of the FAT. ● Knowledge of the FAT was very poor, with 92.5% of participants having never heard of it.
ix. Ultra-runners' response to sports psychology interventions			
McCormick et al., 2018	29 competitors in a 97-km (60-mi) UM (4 ♀, 25 ♂)	Participants were randomised to a group that received a motivational self-talk intervention or a control group and also completed measures of self-efficacy, perceived control, performance expectations and motivation before the intervention and before the race.	● The motivational self-talk intervention did not affect pre-race self-efficacy, perceived control, performance expectations or motivation. ● There was no difference in race performance between the intervention group and the control group. ● Most participants in the intervention group found the intervention helpful and continued to use it in races and training 6 months after the race.
x. Case studies			
Joesting, 1981	1 UR who completed an 80.5-km (50-mi) solo run (♀)	The study participant completed the 'Today' form of the MAACL before, during and after the run.	● There were no significant differences in pre-run, intra-run and post-run levels of depression, anxiety and hostility.
Bull, 1988	1 UR who completed a 20-day, 800-km (497-mi) run (♂)	The investigator gave a qualitative description of the study participant's motivations for undertaking the run and his cognitive processes during the run.	● The participant's motivations were initially mostly intrinsic and related to his need to develop feelings of competence but they became more extrinsic as he became the focus of media attention during the run. ● The participant experienced both associative and dissociative thoughts during the run. ● Associative thinking was associated with superior running performance.

(*continued on next page*)

Table 1 (*continued*)

Study	Population	Methods	Relevant findings
Bull, 1989	1 UR who completed a 20-day, 800-km (497-mi) run (♂)	The investigator gave a qualitative description of a sports psychology consulting intervention provided by him to the study participant before and during the run.	● The intervention consisted of four phases: (a) establishing rapport; (b) forming a psychological profile of the participant; (c) developing an appropriate mental training program; and (d) ongoing evaluation of the participant's progress and crisis intervention.
Kirkby, 1996	1 competitor in a 48-h UM (♀)	The study participant rated her mood state and pain intensity levels and described her thoughts every 35 min during the race and completed the POMS-BI serially before and after the race.	● The participant's mood state decreased and her pain levels increased over the course of the race. ● Pain levels accounted for 90% of the variance of mood state. ● All POMS-BI scales showed changes post-race and all except the clear-headed-confused scale returned to baseline within 1 month after race. ● 70.6% of the thoughts described by the participant during the race were associative and 29.4% dissociative.
Johnson et al., 2016	1 UR who completed a 3641-km (2262-mi), transcontinental run (♀)	The study participant completed the POMS and EmRecQ and reported her RPE before, during and after the run and also participated in a narrative interview 9 months after the run.	● Total EmRecQ score was higher during the race than after it. ● RPE was positively correlated with EmRecQ score and negatively correlated with TMD on the POMS. ● The attributes that the participant identified as assisting her to complete the run fell into four categories: motivation, group cohesiveness, self-awareness and mental stamina.

Abbreviations: ACL, Adjective Checklist; BAS, Body Alienation Scale; BRUMS, Brunel Mood Scale; COWAT, Controlled Oral Word Association Test; CPT, Cold Pressor Test; CRS, Commitment to Running Scale; DR, distance runner; EAI, Exercise Addition Inventory; EAT-26, Eating Attitudes Test-26; EDI, Eating Disorder Inventory; EDS-R, Exercise Dependence Scale-Revised; EEG, electroencephalography; EI, enactive interview; EmIS, Emotional Intelligence Scale; EmRecQ, Emotional Recovery Questionnaire; ExIS, Exercise Identity Scale; FAST, Female Athlete Screening Tool; FAT, female athlete triad; FFS, Flow State Scale; LEAF-Q, Low Energy Availability in Females Questionnaire; GI, gastrointestinal; GSES, General Self-Efficacy Scale; HC, healthy control; HMR, half-marathon runner; International Affective Picture System, IAPS; MAACL, Multiple Affect Adjective Checklist; MBTI, Myers-Briggs Type Indicator; MFSI-SF, Multidimensional Fatigue Symptom Inventory - Short Form; MMPI, Minnesota Multiphasic Personality Inventory; MOMS, Motivations of Marathoners Scale; MR, marathon runner; MSC, mental status changes; NAS, Negative Addiction Scale; NEO-FFI, NEO-Five Factor Inventory; PHNS, Philosophies of Human Nature Scale; POMS, Profile of Mood States; POMS-BI, the bipolar form of the POMS; PSQ, Perception of Success Questionnaire; RESTQ-Sport, Recovery–Stress Questionnaire for Athletes; RPE, rating of perceived exertion; SD, standard deviation; SLSS, Self-Loathing Subscale; SMI, Self-Motivation Inventory; SOQ, Sport Orientation Questionnaire; SSS, Sensation Seeking Scale; STAI, State-Trait Anxiety Inventory; SVL, state of vitality loss; SVP, state of vitality preservation; SVR, state of vitality revival; TCI, Temperament and Character Inventory; TIPI, Ten-Item Personality Inventory; TMD, Total Mood Disturbance; TMT, Trail Making Test; TSCI, Trait Sport-Confidence Inventory; UM, ultra-marathon; UMACL, UWIST Mood Adjective Checklist; UR, ultra-runner.

Nicolas, Banizette, & Millet, 2011; Tharion et al., 1988, 1990; Wollseiffen et al., 2016). Eight of these studies utilised the Profile of Mood States (POMS) (McNair, Lorr, & Droppleman, 1971) or the Brunel Mood Scale (BRUMS) (Terry, Lane, Lane, & Keohane, 1999), which is derived from the POMS (Anglem et al., 2008; Graham et al., 2012; Hoffman & Hoffman, 2008; Lane & Wilson, 2011; Micklewright et al., 2009; Rauch et al., 1988; Tharion et al., 1990, 1988). The POMS and BRUMS measure six mood states: anger, confusion, depression, fatigue, tension and vigour. The remaining studies in this sub-category used the Emotional Intelligence Scale, UWIST Mood Adjective Checklist (UMACL), French version of the Recovery–Stress Questionnaire for Athletes (RESTQ-Sport), Flow State Scale and MoodMeter® computer program (Lane & Wilson, 2011; Nicolas et al., 2011; Wollseiffen et al., 2016). The results of the studies utilising the POMS or BRUMS display a high level of consistency. Seven studies found that running an ultra-marathon (or a stage of a multi-stage ultra-marathon) was associated with an increase in fatigue and a decrease in vigour (Anglem et al., 2008; Graham et al., 2012; Lane & Wilson, 2011; Micklewright et al., 2009; Rauch et al., 1988; Tharion et al., 1990, 1988). Four of these studies found that tension was also significantly reduced after an ultra-marathon (Anglem et al., 2008; Rauch et al., 1988; Tharion et al., 1990, 1988).

Three studies monitored participants' mood states serially in the period of time following an ultra-marathon (Anglem et al., 2008; Nicolas et al., 2011; Tharion et al., 1990). Each of these studies found that between one week and one month was required for complete resolution of the mood alterations caused by ultra-running, including the changes in fatigue, vigour and tension. Two studies identified variables that were associated with the mood changes that occurred during or after an ultra-marathon. Lane and Wilson (2011) found that trait emotional intelligence predicted scores on multiple scales of the POMS and UMACL during a multi-stage ultra-marathon. Micklewright et al. (2009) found that the discrepancy between a runner's predicted finishing time and their actual finishing time was related to post-race Total Mood Disturbance (TMD), confusion and vigour on the POMS. The other studies in this sub-category examined a range of questions. Wollseiffen et al. (2016) assessed the mood states and 'flow state' of a group of ultra-runners hourly during a 6-h running session. They found that perceived psychological relaxation and flow state increased during the first hour of running but decreased thereafter. Hoffman and Hoffman (2008) administered the POMS to a group of ultra-runners, a group of regular moderate exercisers and a group of non-exercisers prior to and after a session of aerobic exercise. They found that TMD decreased after the session for all three groups but the size of the effect was approximately double for the ultra-runners and regular moderate exercisers compared with the non-exercisers. In the final study in this sub-category, by Longman et al. (2017), competitors in a 165.1-km (102.6-mi) ultra-marathon reported arousal levels in response to sexually provocative images before and after the race and the ratings were found to be significantly lower after the race.

3.2.3. Ultra-runners' cognitive processes during races

One study investigated ultra-runners' cognitive processes during races (Acevedo et al., 1992). This study drew upon the distinction first proposed by Morgan and Pollock (1977) between 'associative' cognitive processes, in which attention is focussed on internal sensations experienced during running, such as sensations arising from the lower limbs or sensations associated with respiration, and 'dissociative' cognitive processes, in which attention is focussed away from these sensations. Approximately 50% of the ultra-runners who took part in the study reported experiencing mainly internally focussed thoughts during races while 50% reported experiencing mainly externally focussed thoughts. About 75% of the thoughts described in response to an open-ended question about cognitive processes during races were externally focussed, however. Participants reported using a variety of cognitive strategies during training and racing, including visualisation, reading pre-race paraphernalia, setting goals, self-talk and thought control.

3.2.4. Ultra-runners' cognitive function

Nine studies examined ultra-runners' cognitive function (Cona et al., 2015; Doppelmayr et al., 2005; Glace, Murphy, & McHugh, 2002; Hurdiel et al., 2015; Lucas et al., 2009; Martínez-Navarro et al., 2016; Tonacci et al., 2017, 2016; Wollseiffen et al., 2016). These studies assessed various domains of cognitive function, including attention, working memory, information processing speed, verbal fluency and executive function. Six studies utilised formal tests of cognitive function (Doppelmayr et al., 2005; Hurdiel et al., 2015; Lucas et al., 2009; Martínez-Navarro et al., 2016; Tonacci et al., 2017; Wollseiffen et al., 2016). Two of these studies found that cognitive function was reduced after an ultra-marathon (Doppelmayr et al., 2005; Hurdiel et al., 2015) while four studies either failed to find any statistically significant differences between pre-race and post-race cognitive function or found that cognitive function was improved post-race (Lucas et al., 2009; Martínez-Navarro et al., 2016; Tonacci et al., 2017; Wollseiffen et al., 2016). Two studies treated impaired olfactory function as a 'biomarker' of cognitive impairment and investigated the effect of running an ultra-marathon on olfactory function (Tonacci et al., 2016, 2017). Both of these studies found that olfactory function was reduced after an ultra-marathon. One study investigated whether competitors in a 161-km (100-mi) ultra-marathon experienced any changes in their mental status such as confusion or disorientation during the race (Glace et al., 2002). Ten of the 19 participants reported mental status changes, with most changes occurring after 88 km (54.7 mi). In the final study in this sub-category, the cognitive function of a group of competitors in an 80-km (49.7-mi) ultra-marathon was assessed prior to the race using an inhibitory control task and a dual-task paradigm that incorporated a working memory task and a prospective memory task (Cona et al., 2015). It was found that faster runners in the race outperformed slower runners on these tests. In particular, faster runners were more accurate on the inhibitory control task in trials requiring motor inhibition and had shorter response times in the dual-task paradigm in trials where a prospective memory cue with a positive or negative emotional valence was given.

3.2.5. Ultra-runners' pain perception

Two studies investigated ultra-runners' pain perception (Freund et al., 2013; Hoffman, Lee, Zhao, & Tsodikov, 2007). In the first study, competitors in a 161-km (100-mi) race underwent a test of pressure pain sensitivity before and after the race and evidence was found for a modest exercise-induced analgesic effect following the race but only in the faster runners (Hoffman et al., 2007). In the other study, the pain tolerance of a group of competitors in a 64-day, 4487-km (2788-mi) ultra-marathon and a group of age- and gender-matched controls was measured prior to the race using the cold pressor test (Freund et al., 2013). The ultra-runners displayed considerably higher cold pain tolerance than the controls. None of the ultra-runners withdrew their hand from the water (which was cooled to < 2 °C) during the 3-min test while the mean immersion time for the control group was 96 s.

3.2.6. Ultra-runners' motivations for engaging in ultra-running

Six studies explored ultra-runners' motivations for engaging in ultra-running (Doppelmayr & Molkenthin, 2004; Ferrer, Baumann, Brandenberger, Kyle J. Ellis, & Otis, 2015; Hanson et al., 2015; Hashimoto et al., 2006; Krouse et al., 2011; Kruger & Saayman, 2013). Five of these studies used the Motivations of Marathoners Scales (MOMS) developed by Masters, Ogles, and Jolton (1993) or a system for classifying ultra-runners' motivations based on the MOMS (Doppelmayr & Molkenthin, 2004; Ferrer, Baumann, Brandenberger, Ellis, & Otis, 2015; Hanson et al., 2015; Hashimoto et al., 2006; Krouse et al., 2011). The remaining study used a questionnaire developed by the investigators (Kruger & Saayman, 2013). All of the studies had similar findings. In five studies, the most commonly cited or most important motivation for engaging in ultra-running was to achieve personal goals or to feel a sense of achievement (Doppelmayr & Molkenthin, 2004; Hanson et al., 2015; Hashimoto et al., 2006; Krouse et al., 2011; Kruger & Saayman, 2013). Health-related reasons were the most or second-most common or important motivation in three studies (Ferrer et al., 2015; Hanson et al., 2015; Krouse et al., 2011) and self-esteem reasons were the third-most common or important motivation in three studies (Doppelmayr & Molkenthin, 2004; Hanson et al., 2015; Krouse et al., 2011). By contrast, competing with other ultra-runners was the least or second-least important motivation in four studies (Ferrer et al., 2015; Hanson et al., 2015; Krouse et al., 2011; Kruger & Saayman, 2013). Ferrer et al. (2015) examined whether there is a relationship between motivations for ultra-running and race performance and found that health- and weight-related motivations were negatively associated with mean running speed but positively associated with total distance covered during a 24-h ultra-marathon.

3.2.7. Ultra-runners' phenomenology

Seven studies investigated how ultra-runners themselves describe their experiences of ultra-running (Crust, Nesti, & Bond, 2010; Hanold, 2010; Holt, Lee, Kim, & Klein, 2014; Jaeschke, Sachs, & Dieffenbach, 2016; Philippe, Rochat, Vauthier, & Hauw, 2016; Rochat, Hauw, Antonini Philippe, Crettaz von Roten, & Seifert, 2017; Simpson, Post, Young, & Jensen, 2014). In all of these studies, data were collected by interviewing ultra-runners about their experiences of a particular ultra-marathon or their ultra-running experiences generally. In some studies, data were collected from additional sources such as focus groups or written materials produced by participants. In five studies, data analysis consisted of the investigators identifying themes emerging from participants' responses (Crust et al., 2010; Hanold, 2010; Holt et al., 2014; Jaeschke et al., 2016; Simpson et al., 2014). There is considerable overlap in the themes identified in these studies. First, in three studies, participants commented that ultra-running was for them associated with a drive to explore their physical and mental limits (Crust et al., 2010; Hanold, 2010; Simpson et al., 2014). This drive was described by a participant in the study by Simpson et al. (2014) as follows:

[Ultra-running is] definitely about proving to myself, testing myself, looking for the edges, for the limits and knowing that in these races I'm not just pushing myself on limits like speed, like when you do marathons. With these you are pushing and it's 'can I do it at all?', 'what can go wrong?', 'what's going to break?', 'how am I going to deal with that?' So pushing things until something breaks is definitely part of it.

Secondly, participants in three studies commented on the camaraderie that exists within the ultra-running community and the support that runners provide to each other during races (Holt et al., 2014; Jaeschke et al., 2016; Simpson et al., 2014). Thirdly, participants in three studies noted that, in the ultra-running community, a runner is usually regarded as having been successful if they finish a race (Hanold, 2010; Holt et al., 2014; Simpson et al., 2014). Finishing is viewed as very important but, except among elite runners, finishing time and finishing position are considered relatively unimportant. Finally, in three studies, participants expressed the view that pain is a normal part of ultra-running (Crust et al., 2010; Hanold, 2010; Simpson et al., 2014), with participants in two studies commenting that pain arising during running is only concerning if it differs in some way from the pain that ultra-runners expect to experience (Hanold, 2010; Simpson et al., 2014). In two studies, participants were asked what it means to be a 'mentally tough' ultra-runner (Crust et al., 2010; Jaeschke et al., 2016). There is some overlap in the findings of these studies, with participants in both studies identifying the ability to persevere in the face of setbacks and the ability to maintain a sense of perspective as elements of mental toughness.

In the remaining two studies in this sub-category, the investigators did not attempt to identify themes but rather undertook a complex coding process in which participants' experiences during races were divided into discrete 'units of meaning', which were then categorised into 'sequences of experience' (Philippe et al., 2016; Rochat et al., 2017). One of these studies explored the experiences of ultra-runners who withdrew from races (Philippe et al., 2016). It found that participants' experiences were typically composed of seven representative sequences of experience, which tended to occur in a particular order and which culminated in the decision to withdraw from the race. In the other study, the sequences of experience of competitors in various ultra-marathons ranging in length from 50 km (31 mi) to 173 km (107 mi) were categorised into one of three 'vitality states': a state of vitality preservation (SVP), a state of vitality loss (SVL) or a state of vitality revival (SVR) (Rochat et al., 2017). It was found that participants who finished their races had significantly more sequences in SVP and fewer sequences in SVL than non-finishers.

3.2.8. Ultra-runners' psychopathological traits or symptoms

Seven studies investigated whether ultra-running is associated with psychopathological traits or symptoms (Allegre et al., 2007; Folkins & Wieselberg-Bell, 1981; Folscher, Grant, Fletcher, & Janse van Rensberg, 2015; Lantz et al., 2004; Pierce et al., 1993; Szabo et al., 2013; Weight & Noakes, 1987). Three studies examined whether there is an association between ultra-running and eating disorders (Folscher et al., 2015; Lantz et al., 2004; Weight & Noakes, 1987). One study found a low prevalence of the features of anorexia nervosa in female distance runners generally but a prevalence of these features of 20% in a small population of elite ultra-runners (Weight & Noakes, 1987). In another study, the Female Athlete Triad Screening Tool (FAST) was administered to a large population of female ultra-runners (Folscher et al., 2015). 5.2% of participants had FAST scores indicative of a clinical eating disorder while 26.8% had scores indicative of a subclinical eating disorder. The third study found that disordered eating behaviours in a population of male and female ultra-runners were associated with identification with the exercise role and injury tolerance (Lantz et al., 2004). Three studies investigated whether ultra-running is associated with exercise dependence (Allegre et al., 2007; Pierce et al., 1993; Szabo et al., 2013). Although it is not recognised in the current edition of the American Psychiatric Association's Diagnostic and Statistical Manual of Mental Disorders (2013), some researchers have proposed that exercise dependence is a distinct form of psychopathology, analogous to other behavioural addictions such as gambling disorder (Landolfi, 2013). Two of these studies examined the prevalence of at-risk status for exercise dependence in populations of ultra-runners, with one study reporting a prevalence of 3.2% (Allegre et al., 2007) and the other a prevalence of 17% (Szabo et al., 2013). The third study found a relationship between runners' scores on an exercise addiction scale and the length of their running events, with ultra-runners having higher scores than marathoners, and ultra-runners and marathoners having higher scores than 5-km (3.11-mi) runners and recreational runners (Pierce et al., 1993). In the final study in this sub-category, a group of competitors in a 161-km (100-mi) ultra-marathon completed the Minnesota Multiphasic Personality Inventory (MMPI), a measure of adult psychopathology (Folkins & Wieselberg-Bell, 1981). Although the mean scores for all MMPI scales were within the normal range, participants who finished the race had significantly more deviant scores than non-finishers on various scales, including the psychopathic deviant, hysteria, schizophrenia and hypochondriasis scales. A weighted combination of MMPI scales predicted whether runners finished the race with 79% accuracy.

3.2.9. Ultra-runners' response to sports psychology interventions

One study examined the effect of a sports psychology intervention on a population of ultra-runners (McCormick, Meijen, & Marcora, 2018). The study was a randomised controlled trial in which competitors in a 97-km (60-mi) ultra-marathon were randomised to either a group that was taught how to use motivational self-talk before the race or a control group. The two groups did not differ significantly with respect to their performance in the race, although most participants in the intervention group found the intervention helpful and continued to use motivational self-talk in training and races six months after the race.

3.2.10. Case studies

Five of the included studies were case studies. Two of these studies relate to a 20-day, 800-km (497-mi) solo run undertaken by an ultra-runner through inhospitable terrain in the Western United States (Bull, 1988, 1989). The investigator for both studies was a sports psychologist who provided a sports psychology intervention to the runner prior to and during the run. One study is a qualitative description of the intervention provided to the runner, including the mental training program developed for him (Bull, 1989). The other study (Bull, 1988) is a description of the runner's motivations for undertaking the run and his cognitive processes during the run. His motivations were initially primarily intrinsic but became more extrinsic as the race progressed and he became the subject of media attention. He experienced both associative and dissociative thoughts during the run, with associative thinking reportedly associated with superior running performance. Another study involved an ultra-runner who completed the MAACL before, during and after an 80.5-km (50-mi) run (Joesting, 1981). There were no significant alterations in her mood during or after the run. In the fourth case study, an ultra-runner rated her mood state and pain intensity levels and described her thoughts every 35 min during a 48-h ultra-marathon (Kirkby, 1996). It was found that her mood state decreased and her pain levels increased over the course of the race, with pain levels accounting for 90% of the variance of mood state. 70.6% of the thoughts she described were associative and 29.4% were dissociative. In the final case study, the participant, who undertook a 3641-km (2262-mi) transcontinental run, completed the POMS and Emotional Recovery Questionnaire (EmRecQ), a measure of positive mood states, and reported her rating of perceived exertion (RPE) (Borg, 1982) before, during and after the run (Johnson, Kenttä, Ivarsson, Alvmyren, & Karlsson, 2016). An association between RPE and mood state was found, with RPE positively correlated with total EmRecQ score and negatively correlated with TMD on the POMS.

4. Discussion

As the results of this review demonstrate, there is a significant body of research into the psychology of ultra-runners. The field is developing rapidly, with over half of the studies included in the review dating from 2010 or later. In general, the results of the included studies display little consistency. For example, the findings of the studies investigating ultra-runners' personality traits are heterogeneous and there is conflicting evidence with respect to some traits such as self-motivation and extraversion (Hashimoto et al., 2006; Hughes et al., 2003; McCutcheon & Yoakum, 1983; Rauch et al., 1988). Similarly, the results of studies investigating the effects of ultra-running on cognitive function are mixed and it remains unclear whether ultra-running acutely causes an impairment in cognitive function (Doppelmayr et al., 2005; Hurdiel et al., 2015; Lucas et al., 2009; Martínez-Navarro et al., 2016; Tonacci et al., 2017; Wollseiffen et al., 2016).

There are three areas where it appears possible to draw conclusions, however. First, the acute effects of ultra-running on mood have been reasonably well studied and these effects appear to include an increase in fatigue and a decrease in vigour and tension. This profile of affective changes is similar to that reported in marathon runners following a race (Hassmén & Blomstrand, 1991) but differs from the positive mood changes that follow shorter sessions of aerobic exercise (Reed & Ones, 2006). It is unsurprising that very prolonged endurance exercise results in increased fatigue and decreased vigour. The effect of ultra-running on tension is more interesting and various explanations have been proposed for it, including explanations based on the anxiolytic effect of aerobic exercise generally (Rauch et al., 1988) and explanations based on the resolution of pre-race anxieties relating to performance and the possibility of injury (Tharion et al., 1990). A consensus also appears to be developing within the literature regarding the duration of the mood changes caused by ultra-running, with all of the studies that examined this question finding that between one week and one month was required for these changes to resolve.

Secondly, studies investigating ultra-runners' motivations for engaging in their sport have nearly universally found that the most important motivating factor is the opportunity to achieve personal goals. This appears to differentiate ultra-runners from marathoners, as marathoners' motivations for running are more mixed, with most studies finding that self-esteem reasons and health-related reasons are at least as important for them as personal goal achievement (Havenar & Lochbaum, 2007; Masters & Ogles, 1995; Ogles & Masters, 2000, 2003). One possible explanation for this difference is that ultra-marathons vary widely in distance and ultra-runners are therefore able to select races that will be very challenging for them to complete. In this way, ultra-running offers runners the opportunity to set themselves extremely challenging task-oriented goals. The same opportunity does not exist in marathon running where the race distance is fixed (although runners can of course set goals with respect to finishing time or finishing position).

Finally, a relatively consistent body of findings is emerging from phenomenological studies of ultra-runners. One of the most interesting findings to arise from these studies is the observation that ultra-runners tend to be people who experience a strong drive to explore their physical and mental limits. It is possible that this drive represents a distinct personality trait associated with ultra-running and possibly other ultra-endurance sports. The question of whether such a 'limits-exploring' trait exists and if so how to characterise and measure it does not yet appear to have received any attention from personality psychologists.

There are a number of limitations of the included studies that should be mentioned here. First, many of the studies had very small samples. Twenty studies involved a sample of 19 participants or fewer. Only one of these studies included a power calculation (Micklewright et al., 2009) and at least some of them may have been under-powered with respect to the effects they were investigating. The issue of under-powering is a pervasive one in psychological research generally (Maxwell, 2004; Szucs & Ioannidis, 2017).

Secondly, some of the included studies used psychometric instruments that were not well suited to answering the questions that the studies sought to investigate. For instance, of the nine studies investigating ultra-runners' personality traits, only two studies used inventories based on the five-factor model (FFM) of personality (Hughes et al., 2003; Teranishi Martinez & Scott, 2016), despite this model having achieved something close to consensus among personality researchers (Allen, Greenlees, & Jones, 2013). One study used the Myers-Briggs Type Indicator, a type-based inventory whose psychometric validity has been questioned (Pittenger, 2005). If, as is to be hoped, future research in this area makes greater use of FFM inventories, it will be interesting to note whether ultra-runners have a similar personality profile to regular exercise participants, with increased extraversion and conscientiousness and reduced neuroticism (Rhodes & Smith, 2006), or some other personality profile.

Thirdly, some of the included studies drew upon normative data that was of limited relevance or applicability. Demographic studies of ultra-runners indicate that they are predominantly male, are older than other distance runners, with a mean age of around 45 years, and tend to be well educated and to work in white-collar professions (Hoffman & Fogard, 2012; Hoffman, Chen, & Krishnan, 2014). As Hughes et al. (2003) have observed, this means that some normative data has limited relevance to ultra-runners. For instance, their finding that ultra-runners participating in a 161-km multi-disciplinary race were less disinhibited than the general population may have been an artefact arising from the difference in age between the runners and the norm group for the SSS, as disinhibition decreases with age. The study by Acevedo et al. (1992) provides an example of the weak use of normative data. In this study, a group of ultra-runners was administered the SOQ and the runners' responses were compared to those of a norm group consisting of college students enrolled in non-competitive physical activity skills classes. The runners were found to be more competitive and goal-oriented but less win-oriented than this norm group. There are several different norm groups for the SOQ, however, and if Acevedo and colleagues had compared the runners to a norm group consisting of college students enrolled in *competitive* physical activity skills classes, they would have found that the runners were *less* competitive than this group, although the findings with respect to goal-orientation and win-orientation would have remained (Gill & Deeter, 1988). This suggests that their conclusion that ultra-runners are more competitive than 'other athletes' is, at the very least, an over-simplification.

Fourthly, the included studies generally reported little information about the performance levels of the ultra-runners who participated in the studies. Some studies reported information about participants' running history or training habits but few included data relating to anthropometric parameters such as body fat percentage or physiological parameters such as maximum oxygen uptake (VO_{2max}). Factors that have been found to predict ultra-marathon performance include training volume and intensity (Knechtle, Knechtle, Rosemann, & Lepers, 2010; Tanda & Knechtle, 2015), best marathon time (Knechtle, Knechtle, Rosemann, & Lepers, 2011a), skinfold thickness (Knechtle, Knechtle, Rosemann, & Senn, 2011b), VO_{2max} (Davies & Thompson, 1979; Fornasiero et al., 2017) and peak treadmill velocity during the VO_{2max} test (Noakes, Myburgh, & Schall, 1990). The lack of information about performance levels is regrettable because ultra-runners of different performance levels may differ in important ways. In this regard, a system for classifying the performance level of distance runners, including ultra-runners, similar to the system proposed by De Pauw et al. (2013) for cyclists, would be valuable. Such a system would likely draw upon anthropometric and physiological parameters and the use of it would therefore require pre-experimental testing to measure these parameters.

Finally, most of the included studies were uncontrolled. This limitation is particularly relevant to the studies investigating the effects of ultra-running on mood and cognitive function. Without a control group, it is difficult to know whether effects that were detected were due to the running element of an ultra-marathon or some other element of the race. An example of an important non-running element of an ultra-marathon is sleep deprivation. Completing an ultra-marathon often requires runners to endure significant sleep deprivation, which is known to impact on both mood and cognitive function (Alhola & Polo-Kantola, 2007; Babson, Trainor, Feldner, & Blumenthal, 2010). In order to disentangle the effects of prolonged running from those of sleep deprivation, studies would need to include a control group that experienced any sleep deprivation that the ultra-runner participants were required to undergo but did not perform any running.

Future research in this area should ideally involve large samples, utilise appropriate psychometric instruments, compare ultra-runners to relevant normative populations, include information about the performance level of the ultra-runners studied and, particularly if a causal relationship is being investigated, make use of control groups. There are a number of promising avenues for future research. First, although it has not been particularly fruitful to date, research into ultra-runners' personality traits should continue. Such research could potentially have applications in the field of public health. Ultra-runners perform an extraordinary amount of physical exercise. Knechtle (2012) estimates that the average weekly training distance of male ultra-runners is 85.0 km, nearly double that of male recreational marathoners (Rüst et al., 2012). Although the health impacts of ultra-endurance training remain controversial (Hoffman & Krishnan, 2014; Lee, Morrison, Isserow, Heilbron, & Krahn, 2016), investigating the personality traits of ultra-runners could shed light on the psychological factors that contribute to a person's physical activity levels. Such knowledge could be relevant to efforts to design interventions to improve physical activity levels, which is a global public health priority (Kohl et al., 2012). Secondly, the finding of Freund et al. (2013) that ultra-runners have considerably higher pain tolerance than non-running controls warrants further research into ultra-runners' pain perception. Abnormally high pain tolerance may partially explain ultra-runners' ability to persist with endurance exercise for extremely long periods of time. Questions for future investigators include what physiological and psychological factors underlie ultra-runners' enhanced pain tolerance, how their pain tolerance compares to that of other athletes and whether elevated pain tolerance is an inherited trait or the result of ultra-endurance training. Finally, the finding of Cona et al. (2015) that inhibitory control and working and prospective memory skills are predictive of ultra-running ability is intriguing and merits further attention. This finding forms part of a recent line of research in which a relationship between cognitive performance and athletic performance has been reported (Martin et al., 2016; Vestberg, Gustafson, Maurex, Ingvar, & Petrovic, 2012). Future studies should clarify the exact nature of the cognitive advantages associated with ultra-running ability and should compare these with the advantages that have been found to be predictive of ability in other sports. They should also investigate why faster runners possess these advantages and whether it is due to some form of cognitive skills transfer, as has been hypothesised for athletes in general (Jacobson & Matthaeus, 2014).

5. Conclusion

Research into the psychology of ultra-runners is a rapidly developing area within sports psychology. The existing literature sheds some light on the mood effects of ultra-running, the motivations of ultra-runners for engaging in their sport and the phenomenology of ultra-running. There is much that remains to be learned, however. A number of promising avenues for future research exist. These include further exploration of ultra-runners' personality traits and pursuing recent findings that ultra-runners have abnormally high pain tolerance and that cognitive performance in various domains is associated with ultra-running ability. Given how little is known regarding these remarkable athletes, it is likely that they will continue to attract the attention of sport psychologists, exercise scientists and other researchers for some time to come.

Disclosure statement

Paul B. Fitzgerald has received equipment for research from MagVenture A/S, Medtronic Ltd, Cervel Neurotech and Brainsway Ltd and funding for research from Neuronetics and Cervel Neurotech. He is on the scientific advisory board for Bionomics Ltd.

Funding

Paul B. Fitzgerald is supported by National Health and Medical Research Council Practitioner Fellowship [APP1078567]. Donna M. Urquhart is supported by an NHMRC Career Development Fellowship [APP1011975]. Sin Ki Ng is a recipient of an Australian Postgraduate Award. Bernadette M. Fitzgibbon is supported by an NHMRC Early Career Fellowship [APP1070073].

Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.psychsport.2018.04.004.

References

Acevedo, E. O., Dzewaltowski, D. A., Gill, D. L., & Noble, J. M. (1992). Cognitive orientations of ultramarathoners. *The Sport Psychologist, 6*(3), 242–252. https://doi.org/. https://doi.org/10.1123/tsp.6.3.242.

Alhola, P., & Polo-Kantola, P. (2007). Sleep deprivation: Impact on cognitive

performance. *Neuropsychiatric Disease and Treatment, 3*(5), 553–567. https://doi.org/10.1016/j.smrv.2012.06.007.
Allegre, B., Therme, P., & Griffiths, M. (2007). Individual factors and the context of physical activity in exercise dependence: A prospective study of "ultra-marathoners". *International Journal of Mental Health and Addiction, 5*(3), 233–243. https://doi.org/10.1007/s11469-007-9081-9.
Allen, M. S., Greenlees, I., & Jones, M. (2013). Personality in sport: A comprehensive review. *International Review of Sport and Exercise Psychology, 6*(1), 184–208. https://doi.org/10.1080/1750984X.2013.769614.
American Psychiatric Association (2013). *Diagnostic and statistical manual of mental disorders* (5th ed.). Washington, DC: American Psychiatric Association Publishing.
Anglem, N., Lucas, S. J. E., Rose, E. A., & Cotter, J. D. (2008). Mood, illness and injury responses and recovery with adventure racing. *Wilderness and Environmental Medicine, 19*(1), 30–38. https://doi.org/10.1580/07-WEME-OR-091.1.
Babson, K. A., Trainor, C. D., Feldner, M. T., & Blumenthal, H. (2010). A test of the effects of acute sleep deprivation on general and specific self-reported anxiety and depressive symptoms: An experimental extension. *Journal of Behavior Therapy and Experimental Psychiatry, 41*(3), 297–303. https://doi.org/10.1016/j.jbtep.2010.02.008.
Borg, G. A. (1982). Psychophysical bases of perceived exertion. *Medicine & Science in Sports & Exercise, 14*(5), 377–381. https://doi.org/. https://doi.org/10.1249/00005768-198205000-00012.
Brown, J. S., & Connolly, D. A. (2015). Selected human physiological responses during extreme heat: The badwater ultramarathon. *The Journal of Strength & Conditioning Research, 29*(6), 1729–1736. https://doi.org/10.1519/jsc.0000000000000787.
Bull, S. (1988). The psychology of an ultra-distance runner — A case study. *British Journal of Physical Education, 19*, 124–126.
Bull, S. (1989). The role of the sport psychology consultant: A case study of ultra-distance running. *The Sport Psychologist, 3*(3), 254–264. https://doi.org/. https://doi.org/10.1123/tsp.3.3.254.
Carmack, M. A., & Martens, R. (1979). Measuring commitment to running: A survey of runners' attitudes and mental states. *Journal of Sport Psychology, 1*(1), 25–42. https://doi.org/10.1123/jsp.1.1.25.
Clemente-Suárez, V. J. (2015). Psychophysiological response and energy balance during a 14-h ultraendurance mountain running event. *Applied Physiology Nutrition and Metabolism, 40*(3), 269–273. https://doi.org/10.1139/apnm-2014-0263.
Cona, G., Cavazzana, A., Paoli, A., Marcolin, G., Grainer, A., & Bisiacchi, P. S. (2015). It's a matter of mind! Cognitive functioning predicts the athletic performance in ultramarathon runners. *PLoS One, 10*(7), e0132943 https://doi.org/10.1371/journal.pone.0132943.
Crust, L., Nesti, M., & Bond, K. (2010). Mental toughness and coping in an ultra-endurance event. *Athletic Insight, 2*(1), 35–54.
Davies, C. T. M., & Thompson, M. W. (1979). Aerobic performance of female marathon and male ultramarathon athletes. *European Journal of Applied Physiology and Occupational Physiology, 41*(4), 233–245. https://doi.org/10.1007/bf00429740.
De Pauw, K., Roelands, B., Cheung, S. S., de Geus, B., Rietjens, G., & Meeusen, R. (2013). Guidelines to classify subject groups in sport-science research. *International Journal of Sports Physiology and Performance, 8*(2), 111–122. https://doi.org/https://doi.org/10.1123/ijspp.8.2.111.
Doppelmayr, M., Finkernagel, H., & Doppelmayr, H. I. (2005). Changes in cognitive performance during a 216 kilometer, extreme endurance footrace: A descriptive and prospective study. *Perceptual & Motor Skills, 100*(2), 473–487. https://doi.org/10.2466/pms.100.2.473-487.
Doppelmayr, M., & Molkenthin, A. (2004). Motivation of participants in adventure ultramarathons compared to other foot races. *Biology of Sport, 21*(4), 319–323.
Ferrer, D. A., Baumann, C. W., Brandenberger, K. J., Ellis, R., & Otis, J. S. (2015). Physical motivation influences race performance over a 24-hour ultra-marathon. *International Journal of Sport Studies, 5*(10), 1162–1169.
Folkins, C., & Wieselberg-Bell, N. (1981). A personality profile of ultramarathon runners: A little deviance may go a long way. *Journal of Sport Behavior, 4*(3), 119–127.
Folscher, L. L., Grant, C. C., Fletcher, L., & Janse van Rensberg, D. C. (2015). Ultramarathon athletes at risk for the female athlete triad. *Sports Medicine - Open, 1*(1), 29. https://doi.org/10.1186/s40798-015-0027-7.
Fornasiero, A., Savoldelli, A., Fruet, D., Boccia, G., Pellegrini, B., & Schena, F. (2017). Physiological intensity profile, exercise load and performance predictors of a 65-km mountain ultra-marathon. *Journal of Sports Sciences, 36*(11), 1287–1295. https://doi.org/10.1080/02640414.2017.1374707.
Freund, W., Weber, F., Billich, C., Birklein, F., Breimhorst, M., & Schuetz, U. H. (2013). Ultra-marathon runners are different: Investigations into pain tolerance and personality traits of participants of the TransEurope FootRace 2009. *Pain Practice, 13*(7), 524–532. https://doi.org/10.1111/papr.12039.
Gill, D. L., & Deeter, T. E. (1988). Development of the sport orientation questionnaire. *Research Quarterly for Exercise & Sport, 59*(3), 191–202. https://doi.org/10.1080/02701367.1988.10605504.
Glace, B., Murphy, C., & McHugh, M. (2002). Food and fluid intake and disturbances in gastrointestinal and mental function during an ultramarathon. *International Journal of Sport Nutrition and Exercise Metabolism, 12*(4), 414–427.
Graham, S. M., McKinley, M., Chris, C. C., Westbury, T., Baker, J. S., Kilgore, L., et al. (2012). Injury occurrence and mood states during a desert ultramarathon. *Clinical Journal of Sport Medicine, 22*(6), 462–466. https://doi.org/10.1097/JSM.0b013e3182694734.
Hanold, M. T. (2010). Beyond the marathon: (De)construction of female ultrarunning bodies. *Sociology of Sport Journal, 27*(2), 160–177. https://doi.org/. https://doi.org/10.1123/ssj.27.2.160.
Hanson, N., Madaras, L., Dicke, J., & Buckworth, J. (2015). Motivational differences between half, full and ultramarathoners. *Journal of Sport Behavior, 38*(2), 180–191.
Hashimoto, M., Hagura, N., Kuriyama, T., & Nishiyamai, M. (2006). Motivations and psychological characteristics of Japanese ultra-marathon runners using Myers-Briggs Type Indicator. *Japanese Journal of Health and Human Ecology, 72*(1), 15–24. https://doi.org/10.3861/jshhe.72.15.
Hassmén, P., & Blomstrand, E. (1991). Mood change and marathon running: A pilot study using a Swedish version of the POMS test. *Scandinavian Journal of Psychology, 32*(3), 225–232. https://doi.org/https://doi.org/10.1111/j.1467-9450.1991.tb00872.x.
Havenar, J., & Lochbaum, M. (2007). Differences in participation motives of first-time marathon finishers and pre-race dropouts. *Journal of Sport Behavior, 30*(3), 270.
Hoffman, M. D., Chen, L., & Krishnan, E. (2014). Body mass index and its correlates in 1,212 ultramarathon runners: Baseline findings from the ULTRA study. *Journal of Physical Activity and Health, 11*(8), 1549–1555. https://doi.org/10.1123/jpah.2013-0056.
Hoffman, M. D., & Fogard, K. (2012). Demographic characteristics of 161-km ultramarathon runners. *Research in Sports Medicine, 20*(1), 59–69. https://doi.org/10.1080/15438627.2012.634707.
Hoffman, M. D., & Hoffman, D. R. (2008). Exercisers achieve greater acute exercise-induced mood enhancement than nonexercisers. *Archives of Physical Medicine and Rehabilitation, 89*(2), 358–363. https://doi.org/10.1016/j.apmr.2007.09.026.
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. https://doi.org/10.1371/journal.pone.0083867.
Hoffman, M. D., Lee, J., Zhao, H., & Tsodikov, A. (2007). Pain perception after running a 100-mile ultramarathon. *Archives of Physical Medicine and Rehabilitation, 88*(8), 1042–1048. https://doi.org/. https://doi.org/10.1016/j.apmr.2007.05.004.
Holt, N. L., Lee, H., Kim, Y., & Klein, K. (2014). Exploring experiences of running an ultramarathon. *The Sport Psychologist, 28*(1), 22–35. https://doi.org/10.1123/tsp.2013-0008.
Hughes, S. L., Case, H. S., Stuempfle, K. J., & Evans, D. S. (2003). Personality profiles of Iditasport ultra-marathon participants. *Journal of Applied Sport Psychology, 15*(3), 256–261. https://doi.org/10.1080/10413200390213335.
Hurdiel, R., Peze, T., Daugherty, J., Girard, J., Poussel, M., Poletti, L., ... Theunynck, D. (2015). Combined effects of sleep deprivation and strenuous exercise on cognitive performances during the North Face Ultra Trail du Mont Blanc (UTMB). *Journal of Sports Sciences, 33*(7), 670–674. https://doi.org/10.1080/02640414.2014.960883.
Jacobson, J., & Matthaeus, L. (2014). Athletics and executive functioning: How athletic participation and sport type correlate with cognitive performance. *Psychology of Sport and Exercise, 15*(5), 521–527. https://doi.org/10.1016/J.PSYCHSPORT.2014.05.005.
Jaeschke, A. M. C., Sachs, M. L., & Dieffenbach, K. D. (2016). Ultramarathon runners' perceptions of mental toughness: A qualitative inquiry. *The Sport Psychologist, 30*(3), 242–255. https://doi.org/10.1123/tsp.2014-0153.
Joesting, J. (1981). Affective changes before, during and after a 50-mile run. *Perceptual & Motor Skills, 52*(1), 162. https://doi.org/10.2466/pms.1981.52.1.162.
Johnson, U., Kenttä, G., Ivarsson, A., Alvmyren, I., & Karlsson, M. (2016). An ultra-runner's experience of physical and emotional challenges during a 10-week continental run. *International Journal of Sport and Exercise Psychology, 14*(1), 72–84. https://doi.org/10.1080/1612197X.2015.1035736.
Joslin, J., Worthing, R., Black, T., Grant, W. D., Kotlyar, T., & Wojcik, S. M. (2014). Analysis of weight change and Borg rating of perceived exertion as measurements of runner health and safety during a 6-day, multistage, remote ultramarathon. *Clinical Journal of Sport Medicine, 24*(3), 245–250. https://doi.org/10.1097/jsm.0000000000000019.
Kirkby, R. J. (1996). Ultraendurance running: A case study. *International Journal of Sport Psychology, 27*(1), 109–116.
Knechtle, B. (2012). Ultramarathon runners: Nature or nurture? *International Journal of Sports Physiology and Performance, 7*(4), 310–312. https://doi.org/. https://doi.org/10.1123/ijspp.7.4.310.
Knechtle, B., Knechtle, P., Rosemann, T., & Lepers, R. (2010). Predictor variables for a 100-km race time in male ultra-marathoners. *Perceptual & Motor Skills, 111*(3), 681–693. https://doi.org/10.2466/05.25.pms.111.6.681-693.
Knechtle, B., Knechtle, P., Rosemann, T., & Lepers, R. (2011a). Personal best marathon time and longest training run, not anthropometry, predict performance in recreational 24-hour ultrarunners. *The Journal of Strength & Conditioning Research, 25*(8), 2212–2218. https://doi.org/10.1519/JSC.0b013e3181f6b0c7.
Knechtle, B., Knechtle, P., Rosemann, T., & Senn, O. (2011b). What is associated with race performance in male 100-km ultra-marathoners — anthropometry, training or marathon best time? *Journal of Sports Sciences, 29*(6), 571–577. https://doi.org/10.1080/02640414.2010.541272.
Krouse, R. Z., Ransdell, L. B., Lucas, S. M., & Pritchard, M. E. (2011). Motivation, goal orientation, coaching, and training habits of women ultrarunners. *The Journal of Strength & Conditioning Research, 25*(10), 2835–2842. https://doi.org/10.1519/JSC.0b013e318204caa0.
Kruger, M., & Saayman, M. (2013). Who are the comrades of the comrades marathon? *South African Journal for Research in Sport, Physical Education and Recreation, 35*(1), 71–92.
Landolfi, E. (2013). Exercise addiction. *Sports Medicine, 43*(2), 111–119. https://doi.org/10.1007/s40279-012-0013-x.
Lane, A. M., & Wilson, M. (2011). Emotions and trait emotional intelligence among ultra-endurance runners. *Journal of Science and Medicine in Sport, 14*(4), 358–362. https://doi.org/10.1016/j.jsams.2011.03.001.
Lantz, C. D., Rhea, D. J., & Mesnier, K. (2004). Eating attitudes, exercise identity, and body alienation in competitive ultramarathoners. *International Journal of Sport Nutrition and Exercise Metabolism, 14*(4), 406–418.
Lee, A. K. Y., Morrison, B. N., Isserow, S., Heilbron, B., & Krahn, A. D. (2016). The impact of excessive endurance exercise on the heart. *BC Medical Journal, 58*(4), 203–209.

Liberati, A., Altman, D. G., Tetzlaff, J., Mulrow, C., Gotzsche, P. C., Ioannidis, J. P. A., ... Moher, D. (2009). The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: Explanation and elaboration. *Journal of Clinical Epidemiology, 62*(10), e1–e34. https://doi.org/10.1016/j.jclinepi.2009.06.006.

Longman, D. P., Prall, S. P., Shattuck, E. C., Stephen, I. D., Stock, J. T., Wells, J. C. K., et al. (2017). Short-term resource allocation during extensive athletic competition. *American Journal of Human Biology, 30*(1), e23052. https://doi.org/10.1002/ajhb.23052.

Lucas, S. J. E., Anson, J. G., Palmer, C. D., Hellemans, I. J., & Cotter, J. D. (2009). The impact of 100 hours of exercise and sleep deprivation on cognitive function and physical capacities. *Journal of Sports Sciences, 27*(7), 719–728. https://doi.org/10.1080/02640410902798167.

Martínez-Navarro, I., Chiva-Bartoll, O., Hernando, B., Collado, E., Porcar, V., & Hernando, C. (2016). Hydration status, executive function and response to orthostatism following a 118-km mountain race. *The Journal of Strength & Conditioning Research, 32*(2), 441–449. https://doi.org/10.1519/JSC.0000000000001614.

Martin, K., Staiano, W., Menaspà, P., Hennessey, T., Marcora, S., Keegan, R., ... Rattray, B. (2016). Superior inhibitory control and resistance to mental fatigue in professional road cyclists. *PLoS One, 11*(7), e0159907 https://doi.org/10.1371/journal.pone.0159907.

Masters, K. S., & Ogles, B. M. (1995). An investigation of the different motivations of marathon runners with varying degrees of experience. *Journal of Sport Behavior, 18*(1), 69–79.

Masters, K. S., Ogles, B. M., & Jolton, J. A. (1993). The development of an instrument to measure motivation for marathon Running: The motivations of marathoners scales (MOMS). *Research Quarterly for Exercise & Sport, 64*(2), 134–143. https://doi.org/10.1080/02701367.1993.10608790.

Maxwell, S. E. (2004). The persistence of underpowered studies in psychological research: Causes, consequences, and remedies. *Psychological Methods, 9*(2), 147–163. https://doi.org/10.1037/1082-989X.9.2.147.

McCormick, A., Meijen, C., & Marcora, S. (2018). Effects of a motivational self-talk intervention for endurance athletes completing an ultramarathon. *The Sport Psychologist, 32*(1), 42–50. https://doi.org/10.1123/tsp.2017-0018.

McCutcheon, L. E., & Yoakum, M. E. (1983). Personality attributes of ultramarathoners. *Journal of Personality Assessment, 47*(2), 178–180. https://doi.org/10.1207/s15327752jpa4702_13.

McNair, D., Lorr, M., & Droppleman, L. (1971). *Manual for the profile of mood states.* San Diego: Educational and Industrial Testing Service.

Micklewright, D., Papadopoulou, E., Parry, D., Hew-Butler, T., Tam, N., & Noakes, T. (2009). Perceived exertion influences pacing among ultramarathon runners but post-race mood change is associated with performance expectancy. *South African Journal of Sports Medicine, 21*(4), 167–172. https://doi.org/10.7196/8.2009.v21i4.290.

Morgan, W. P., & Pollock, M. L. (1977). Psychologic characterization of the elite distance runner. *Annals of the New York Academy of Sciences, 301*(1), 382–403. https://doi.org/10.1111/j.1749-6632.1977.tb38215.x.

Nicolas, M., Banizette, M., & Millet, G. Y. (2011). Stress and recovery states after a 24 h ultra-marathon race: A one-month follow-up study. *Psychology of Sport and Exercise, 12*(4), 368–374. https://doi.org/10.1016/j.psychsport.2011.03.005.

Nieman, D. C., Dumke, C. L., Henson, D. A., McAnulty, S. R., Gross, S. J., & Lind, R. H. (2005). Muscle damage is linked to cytokine changes following a 160-km race. *Brain, Behavior, and Immunity, 19*(5), 398–403. https://doi.org/10.1016/j.bbi.2005.03.008.

Noakes, T. D., Myburgh, K. H., & Schall, R. (1990). Peak treadmill running velocity during the VO2 max test predicts running performance. *Journal of Sports Sciences, 8*(1), 35–45. https://doi.org/10.1080/02640419008732129.

Ogles, B. M., & Masters, K. S. (2000). Older vs. younger adult male marathon runners: Participative motives and training habits. *Journal of Sport Behavior, 23*(2), 130–143.

Ogles, B. M., & Masters, K. S. (2003). A typology of marathon runners based on cluster analysis of motivations. *Journal of Sport Behavior, 26*(1), 69–85.

Philippe, R. A., Rochat, N., Vauthier, M., & Hauw, D. (2016). The story of withdrawals during an ultra-trail running race: A qualitative investigation of runners' courses of experience. *The Sport Psychologist, 30*(4), 361–375. https://doi.org/10.1123/tsp.2016-0039.

Pierce, E. F., McGowan, R. W., & Lynn, T. D. (1993). Exercise dependence in relation to competitive orientation of runners. *The Journal of Sports Medicine and Physical Fitness, 33*(2), 189–193.

Pittenger, D. J. (2005). Cautionary comments regarding the Myers-Briggs type indicator. *Consulting Psychology Journal: Practice and Research, 57*(3), 210–221. https://doi.org/10.1037/1065-9293.57.3.210.

Rauch, T. M., Tharion, W. J., Strowman, S. R., & Shukitt, B. L. (1988). Psychological factors associated with performance in the ultramarathon. *The Journal of Sports Medicine and Physical Fitness, 28*(3), 237–246.

Reed, J., & Ones, D. S. (2006). The effect of acute aerobic exercise on positive activated affect: A meta-analysis. *Psychology of Sport and Exercise, 7*(5), 477–514. https://doi.org/10.1016/J.PSYCHSPORT.2005.11.003.

Rhodes, R. E., & Smith, N. E. I. (2006). Personality correlates of physical activity: A review and meta-analysis. *British Journal of Sports Medicine, 40*(12), 958–965. https://doi.org/10.1136/bjsm.2006.028860.

Rochat, N., Hauw, D., Antonini Philippe, R., Crettaz von Roten, F., & Seifert, L. (2017). Comparison of vitality states of finishers and withdrawers in trail running: An enactive and phenomenological perspective. *PLoS One, 12*(3), e0173667 https://doi.org/10.1371/journal.pone.0173667.

Simpson, D., Post, P. G., Young, G., & Jensen, P. R. (2014). "It's not about taking the easy road": The experiences of ultramarathon runners. *The Sport Psychologist, 28*(2), 176–185. https://doi.org/10.1123/tsp.2013-0064.

Stuempfle, K. J., & Hoffman, M. D. (2015). Gastrointestinal distress is common during a 161-km ultramarathon. *Journal of Sports Sciences, 33*(17), 1814–1821. https://doi.org/10.1080/02640414.2015.1012104.

Szabo, A., De La Vega, R., Ruiz-Barquin, R., & Rivera, O. (2013). Exercise addiction in Spanish athletes: Investigation of the roles of gender, social context and level of involvement. *Journal of Behavioral Addictions, 2*(4), 249–252. https://doi.org/10.1556/jba.2.2013.4.9.

Szucs, D., & Ioannidis, J. P. A. (2017). Empirical assessment of published effect sizes and power in the recent cognitive neuroscience and psychology literature. *PLoS Biology, 15*(3), e2000797 https://doi.org/10.1371/journal.pbio.2000797.

Tanda, G., & Knechtle, B. (2015). Effects of training and anthropometric factors on marathon and 100 km ultramarathon race performance. *Open Access Journal of Sports Medicine, 6*, 129–136. https://doi.org/10.2147/oajsm.s80637.

Teranishi Martinez, C., & Scott, C. (2016). Trail and ultrarunning: The impact of distance, nature, and personality on flow and well-being. *Psi Chi Journal of Psychological Research, 21*(1), 6–15. https://doi.org/10.24839/2164-8204.JN21.1.6.

Terry, P. C., Lane, A. M., Lane, H. J., & Keohane, L. (1999). Development and validation of a mood measure for adolescents. *Journal of Sports Sciences, 17*(11), 861–872. https://doi.org/10.1080/026404199365425.

Tharion, W. J., McMenemy, D. J., Terry, A. L., & Rauch, T. M. (1990). Recovery of mood changes experienced when running an ultramarathon. *Perceptual & Motor Skills, 71*(3), 1311–1316. https://doi.org/10.2466/pms.71.8.1311-1316.

Tharion, W. J., Strowman, S. R., & Rauch, T. M. (1988). Profile and changes in moods of ultramarathoners. *Journal of Sport & Exercise Psychology, 10*(2), 229–235.

Tonacci, A., Billeci, L., Tartarisco, G., Mastorci, F., Borghini, A., Mrakic-Sposta, S., ... Pratali, L. (2016). A novel application for cognitive evaluation in mountain ultramarathons: Olfactory assessment. *Wilderness and Environmental Medicine, 27*(1), 131–135. https://doi.org/. https://doi.org/10.1016/j.wem.2015.11.013.

Tonacci, A., Mrakic-Sposta, S., Ujka, K., Sansone, F., Ferrisi, A., Giardini, G., ... Pratali, L. (2017). Neurosensory and cognitive modifications in Europe's toughest RandoRaid competition: The transpyrénéa extreme study. *Frontiers in Physiology, 8*(201)https://doi.org/10.3389/fphys.2017.00201.

Vealey, R. S. (1986). Conceptualization of sport-confidence and competitive orientation: Preliminary investigation and instrument development. *Journal of Sport Psychology, 8*(3), 221–246. https://doi.org/10.1123/jsp.8.3.221.

Vestberg, T., Gustafson, R., Maurex, L., Ingvar, M., & Petrovic, P. (2012). Executive functions predict the success of top-soccer players. *PLoS One, 7*(4), e34731 https://doi.org/10.1371/journal.pone.0034731.

Weight, L. M., & Noakes, T. D. (1987). Is running an analog of anorexia? A survey of the incidence of eating disorders in female distance runners. *Medicine & Science in Sports & Exercise, 19*(3), 213–217. https://doi.org/. https://doi.org/10.1249/00005768-198706000-00005.

Wollseiffen, P., Schneider, S., Martin, L. A., Kerherve, H. A., Klein, T., & Solomon, C. (2016). The effect of 6 h of running on brain activity, mood, and cognitive performance. *Experimental Brain Research, 234*(7), 1829–1836. https://doi.org/10.1007/s00221-016-4587-7.

Wortley, G., & Islas, A. A. (2011). The problem with ultra-endurance athletes. *British Journal of Sports Medicine, 45*(14), 1085. https://doi.org/10.1136/bjsports-2011-090399.