Accepted Manuscript

Title: Emotional intelligence and mood states impact on the stress response to a treadmill ultramarathon

Authors: Christopher C.F. Howe, Elizabeth Pummell, Susan Pang, Owen Spendiff, Hannah J. Moir

PII: S1440-2440(18)30923-X
DOI: https://doi.org/10.1016/j.jsams.2019.02.008
Reference: JSAMS 2038

To appear in: *Journal of Science and Medicine in Sport*

Received date: 27 September 2018
Revised date: 14 January 2019
Accepted date: 24 February 2019

Please cite this article as: Howe Christopher CF, Pummell Elizabeth, Pang Susan, Spendiff Owen, Moir Hannah J.Emotional intelligence and mood states impact on the stress response to a treadmill ultramarathon.*Journal of Science and Medicine in Sport* (2019), https://doi.org/10.1016/j.jsams.2019.02.008

This is a PDF file of an unedited manuscript that has been accepted for publication. As a service to our customers we are providing this early version of the manuscript. The manuscript will undergo copyediting, typesetting, and review of the resulting proof before it is published in its final form. Please note that during the production process errors may be discovered which could affect the content, and all legal disclaimers that apply to the journal pertain.

ACCEPTED MANUSCRIPT

Emotional intelligence and mood states impact on the stress response to a treadmill ultramarathon.

Christopher. C.F. Howe [a], Elizabeth. Pummell [a], Susan. Pang [b], Owen. Spendiff [a], Hannah. J. Moir [a]

[a]School of Life Sciences, Pharmacy and Chemistry, Faculty of Science Engineering and Computing, Kingston University, Kingston upon Thames, KT1 2EE, UK

[b]LGC, Queens Road, Teddington, Middlesex, TW11 0LY, UK

Address correspondence to: Dr Hannah Moir BSc, PhD, PGCHE Kingston University Penryhn Road Kingston upon Thames, KT1 2EE, UK

E-mail: H.Moir@Kingston.ac.uk

Abstract

Objectives: Participants of ultramarathon events experience a complex interaction of psychophysiological stressors. Therefore, the purpose of this study was to investigate the role of trait emotional intelligence (trait EI) on mood states and serum cortisol responses to a 80.5km treadmill ultramarathon.

Design: Twelve participants completed an 80.5km time-trial on a motorised treadmill in the fastest possible time.

ACCEPTED MANUSCRIPT

ACCEPTED MANUSCRIPT

Methods: Participants' trait EI was measured prior to the trial. A mood state questionnaire was completed prior (baseline: within two weeks of treadmill ultramarathon), immediately prior (pre: within 30 min of commencing treadmill ultramarathon), at 40.25 km (halfway: during standardised 10 min rest period to allow for venous blood sampling) and on completion of 80.5 km (post: immediately on completion of treadmill ultramarathon), along with serum cortisol concentrations measured at the same time points.

Results: Completion time was 09:00:18±01:14:07 (hh:mm:ss). Significant increase in serum cortisol and total mood disturbance (TMD) was observed throughout the treadmill ultramarathon ($p<0.05$). Participants with higher trait EI displayed a higher post cortisol concentration ($p=0.01$) with no change in TMD, compared to those with low trait EI who displayed a significant increase in TMD between pre and halfway ($p=0.02$).

Conclusion: The treadmill ultramarathon elicited a significant increase in serum cortisol concentration, which was significantly greater in those with a higher trait EI. Those individuals with higher trait EI were more effective at managing their mood, with little change total mood disturbance and perceived effort compared to those with lower trait EI.

Keywords: Psychophysiology; cortisol; ultra-running; mood; endurance

Introduction

With the increasing popularity of ultramarathon participation[1,2], understanding the factors which influence successful performance in such events, is important. Micklewright et al.[3] suggest there are significant cognitive, emotional and motivational challenges involved in ultramarathon participation. Indeed, ultramarathons involve a complex interaction of psychophysiological processes, requiring individuals to overcome fatigue, sleep deprivation,

ACCEPTED MANUSCRIPT

ACCEPTED MANUSCRIPT

extreme muscle damage, gastrointestinal (GI) distress and management of unpleasant emotional states.[3-5]

Emotions have been suggested to predict performance outcomes,[6,7] therefore, effective emotional regulation could be key to successfully meeting performance goals.[8] An individual's ability to regulate and manage emotions is often referred to as their trait emotional intelligence (trait EI).[9] More specifically, trait EI is related to an individual's ability to be aware of their emotions, the effects of these on their thoughts and behaviours, as well as the ability to regulate emotions.[4,10] In a sporting context, trait EI has been associated with pre-competition mood and its relationship with optimal performance, as well as strategies to aid performance during training and competition[6] and the ability to objectively predict performance.[11]

It has been speculated that trait EI is a fundamental variable in the regulation of emotions[9] with emotionally intelligent individuals being more aware of emotions, and the influence of those emotions on their behaviours.[6] Using the 'Profile of Mood States' (POMS), Tharion et al.[12] demonstrated the classic 'iceberg profile' with a decrease in tension and vigor and increase in fatigue pre to post ultramarathon. A decrease in tension has previously been attributed to exercise-induced tension reduction, where exercise distracts from anxiety provoking thoughts[13], which could potentially lead to improved general wellbeing and aid in improving overall performance. However, there is limited information on the tension reduction potential during ultramarathons, which may reflect the characteristics of those individuals drawn to the sport.

Only one study has investigated the relationship between changes in emotional states and trait EI of ultramarathon runners over a six-day event, covering 282km.[4] The authors reported considerable emotional disturbances, which was demonstrated by significant increases in confusion, fatigue and vigor during each run; along with increased happiness post the final stage.[4] Furthermore, runners with lower trait EI reported significant increases in anger

ACCEPTED MANUSCRIPT

and confusion, whereas, runners with higher trait EI reported more pleasant emotional states.[4] A previous study by Micklewright et al.[3] investigated the relationship between post-race mood, perceived exertion and the difference between actual and predicted performance time in a group of eight runners competing in a 73 km mountain ultramarathon. The authors[3] identified an increase in pre-race levels of confusion, which potentially indicates an anticipatory affective state, suggested to be linked to imminent races and their individual pre-race circumstances. Ratings of perceived exertion (RPE) increased linearly throughout the ultramarathon within sustainable RPE limits but increased to less maintainable limits towards the end of the event as confidence in completing the event improved. Interestingly, post-race total mood disturbance (TMD), in which higher scores indicate a more intense perception of mood, was not correlated with RPE[14] suggesting the relationship between sensory feedback and an athlete's affective mood state during an ultramarathon may be mediated by varying psychological factors including ongoing performance appraisal via external feedback. Micklewright et al.[3] also concluded that ultramarathon runners tend to make overly optimistic performance predictions, and that failing to successfully meet pre-race goals leads to unpleasant post-race mood states. There is however, no data to the author's knowledge on whether individuals with higher EI show reduced objective markers of stress from an ultramarathon, and whether or not mood states before, during and after an ultramarathon impact upon physiological markers of stress, perceived exertion and/or overall performance.

A popular physiological biomarker of stress from both physical and psychological stimuli is the hormone cortisol.[15] Typically, stress can be defined as the psychophysiological deterioration brought about by harmful stimuli, such as arousal, exertion, fatigue, pain, fear and concentration.[16] Therefore, it has been suggested that a higher activity of the hypothalamic pituitary adrenal axis brought about by elevations in stress have an association to EI; hence a higher trait EI[4] leading to higher ratio of pleasant to unpleasant emotions.[9] The link between trait EI and markers of stress have been demonstrated by Loborde et al.[7], where tennis players with lower trait EI displayed a greater cortisol response when subjected to a mental arithmetic 'Trier Social Stress Test'. One potential explanation is that those with higher

ACCEPTED MANUSCRIPT

ACCEPTED MANUSCRIPT

trait EI employ more adaptive coping strategies and appraise a potentially stressful situation as a challenge rather than a threat.[17] Therefore, it is hypothesised that ultramarathon runners with higher trait EI should display less of a cortisol response compared to those with lower trait EI.

To our knowledge this is the first study to investigate the effect of a controlled treadmill ultramarathon on the cortisol response, mood states and trait EI in a laboratory environment. This allows for real-time, in-event monitoring of runners, which is problematic during external events due to environmental logistics as well as having to rely on retrospective analysis of performance and mood during the run, which is unlikely to be accurate, as well as removing environmental and geographical variations of different events (altitude, weather, competition).

Methods

Twelve participants (9 male and 3 female; age: 34±7 years, stature: 173.7±7.3 cm, body mass: 68.4±7.4 kg, $\dot{V}O_{2max}$: 60.4±5.8 $ml \cdot kg^{-1} \cdot min^{-1}$, average weekly training 74±27km) with an average 6±7 years (range >25 years) ultramarathon running experience volunteered for the study, and were recruited via social media from the local ultramarathon community. Initially fourteen participants were recruited however, two were excluded from the analysis for non-completion of the total distance. All participants provided written informed consent and the study was approved by the institution's Faculty Ethics Committee. All procedures were conducted in accordance with the Declaration of Helsinki.

Participants visited the laboratory twice separated by a minimum of 48 hours and no longer than a two week time period. During the initial visit participants underwent a discontinuous incremental $\dot{V}O_{2max}$ test where respiratory variables were measured via indirect calorimetry (Oxycon Pro, Vyaire Medical, Illinois, USA and heart rate was measured continously via telemetry (Polar Electro, Oy, Finland); the initial velocity was set at $8 km \cdot h^{-1}$, and was increased by $1.5 km \cdot h^{-1}$ every three minutes until volitional exhaustion.

ACCEPTED MANUSCRIPT

For the second visit an observational study design was employed where participants were required to run at a self-selected pace with the aim to complete the distance of 80.5 km in the fastest possible time, with the exception of repeated controlled velocity bouts at a self-selected velocity for 3 minutes immediately followed by a controlled velocity of $8 km \cdot h^{-1}$ for 3 minutes every 16.1 km, where respiratory variables ($\dot{V}O_2$, $\dot{V}CO_2$, $\dot{V}_E$) were measured via indirect calorimetry and heart rate was measured by telemetry. The use of a controlled velocity bout enabled both inter and intra direct comparison by removing the effect of self-selected velocities.[18] Participants' body mass (kg) was measured pre, at every 16.1 km split and immediately post the treadmill ultramarathon. In order to minimise the effect of the circadian nature of cortisol secretion[19] all trials began at 07:00 ± 1.0 hour. Food and drink was provided *ad libitum* during the entire duration and self-selected according to the participants' preference to replicate habitual ultra-running conditions. All nutritional intake were recorded and analysed through nutritional analysis software (Dietplan 6 Software, Horsham, U.K.).

Participants completed the 33-item trait EI scale[20] which has demonstrated factorial and predictive validity in athletic populations,[6,11] within two weeks of the treadmill ultramarathon. Items included: "When I experience a positive emotion, I know how to make it last" and "I have control over my emotions". Respondents were asked to rate each item using a five-point Likert scale with anchors "strongly disagree" (1) to "strongly agree" (5). The trait EI scores were analysed by separating participants into either above (High trait EI) or below (Low trait EI) the median trait EI.[21] Mood states were assessed using the 24-item BRUMS[22], a shortened version of the POMS. The scale assesses six sub-scales included in the original POMS (tension, anger, fatigue, vigor, confusion and depression). Examples of specific items include; "worried" for "tension"; "annoyed" for anger; "worn-out" for fatigue; "energetic" for vigor; "uncertain" for confusion and "downhearted" for depression. All items were rated on a five-point scale anchored by "not at all" (0) to "extremely" (4). Participants were requested to complete the BRUMS at four time points: Baseline (within two weeks of treadmill ultramarathon); Pre (within 30 mins of commencing the treadmill ultramarathon); Halfway (at

ACCEPTED MANUSCRIPT

40.25km, during standardised 10 min rest period to allow for venous blood sampling), and Post (immediately on completions of treadmill ultramarathon). Participants were instructed to answer as honestly as possible by reflecting on how they felt at that precise moment in time, rather than attempting to provide answers based on any previous BRUMS responses. Raw BRUMS scores were normalised for each of the sub scales, as well as TMD, which was calculated by summing tension, anger, fatigue and confusion and subtracting the vigor score (higher scores indicate poorer mood state).[23] Participants reported their RPE whilst running at a self-selected running velocity as well as during a controlled velocity of 8km·h^{-1} at every 16.1km distance interval from the start of the treadmill time trial, via the standard 6-20 Borg scale.[14]

Serum samples were obtained from venous whole blood collected via venepuncture at rest, in a non-fasted state, before commencement of the trial (pre), at halfway (scheduled 10 min rest period) and immediately on completion of the treadmill ultramarathon (post). An additional 3 h fasted blood sample (baseline) was collected at rest from all participants two weeks prior to the 80.5km. Samples were centrifuged for 10 min at 2000g at 4˚C and serum aliquots stored at −80˚C for subsequent analysis. Serum cortisol concentrations were analysed by competitive ELISA-type electrochemiluminescence carried out on a Multi-Array High Bind 96-well microtiter plate (MSD) and read on a MSD SECTOR Imager 6000 instrument (Meso Scale Discovery, Gaitherburg, MD, USA). The MSD Discovery Workbench v3.0 software was used for data analysis of serum cortisol concentration.

Changes in whole cohort mood across time points were analysed using a repeated measures multivariate analysis of variance (MANOVA). *Post-hoc* analysis was completed using the least-significant difference (LSD) pairwise comparison. The relationship between trait EI score and time to complete the 80.5km time trial was investigated with Pearson's correlation coefficients (r), as was trait EI and post serum cortisol concentrations, for whole cohort data. Changes in RPE over the duration of the ultramarathon at 16.1km intervals at both self-selected velocity and control velocity (8km.h^{-1}) were analysed using two-way

ACCEPTED MANUSCRIPT

repeated measures ANOVA with Bonferroni *post-hoc* analysis for whole cohort data. Changes in serum cortisol and TMD scores between baseline, pre, halfway and post time points were assessed via one-way repeated measures ANOVA with Bonferroni *post-hoc* analysis to identify where significance lies for whole group data. High and low trait EI group's data were also investigated independently via one-way ANOVA with independent t-test *post-hoc* analysis, across time points, for serum cortisol, TMD, and RPE. Further, analysis of differences between high and low trait EI groups where investigated via paired sample t-tests (Table 3). All statistical procedures were completed using IBM SPSS Statistics for Windows 24.0 (Armonk, NY: IBM Corp) where the significance level was set at $p \leq 0.05$.

Results

Whole cohort TMD scores between all-time points significantly increased, $F(1.4, 11)=7.8$, $p=0.008$, $\eta p^2=0.414$ (Fig 1.A). *Post hoc* analysis identified significantly higher TMD scores between baseline and post, as well as between pre and post respectively ($p=0.001$), with no difference observed between baseline and pre, baseline and halfway, pre and halfway and halfway and post ($p>0.05$). The RPE was significantly lower for the controlled velocity of 8km·h^{-1} compared to a self-selected velocity (10.3±1.3 km·h^{-1}) across all 16.1km splits, $F(1, 11)=23.01$, $p=0.001$, $\eta p^2=0.68$ (Table 1) for the whole cohort. There was a main effect for time for serum cortisol levels for the whole cohort, $F(1.7,18.7)=22.34$, $p<0.001$, $\eta p^2=0.67$ (Fig.1) where significant increases were identified between whole cohort baseline and halfway; and baseline and post cortisol levels ($p<0.001$), as well as between pre and halfway; pre and post cortisol levels ($p=0.001$ and $p=0.003$), respectively (Fig 1.B). A significant effect on the BRUMS scores over the four time points (Pillai's Trace, $V=0.88$, $F=2.28$, $p=0.005$, $\eta p^2=0.293$, Observed Power=0.982) was observed, indicating that participants experienced significant mood change across the treadmill ultramarathon. *Post-hoc* analysis identified no significant difference between mood scores over all four time points for; tension, depression and anger ($p>0.05$). However, a significant decrease was observed between both baseline and pre time points to the post time point for the mood sub-scale 'Vigor' ($p=0.015$ and $p=0.01$ respectively).

ACCEPTED MANUSCRIPT

A significant increase was identified for the sub-scale of 'Fatigue' between baseline and halfway ($p=0.04$) and post ($p<0.01$), pre and halfway ($p=0.05$) and post ($p<0.01$), as well as halfway to post ($p=0.02$) (Fig 1.C). There was no significant correlation between whole cohort trait EI score and time to complete the 80.5km time trial ($p>0.05$). However, there was a positive correlation between trait EI and post serum cortisol concentrations, for whole cohort data ($r=0.78$, $p<0.01$).

Trait EI scores were analysed by separating participants into either above (High EI) or below (Low EI) the median trait EI (Table 2). Although there was no effect of time ($p\geq0.05$) on TMD scores for the high trait EI group, a significant increase was observed in the low trait EI group, $F(3,20)=4.9$, $p=0.10$. *Post hoc* analysis revealed a significant increase between baseline and halfway ($p=0.02$) and pre and halfway ($p=0.02$) TMD scores in the low trait EI group. A significant difference was identified between the high and low trait EI groups and serum cortisol response, $F(1,10)=5.5$, $p=0.041$, $\eta p^2=0.35$ (Table 2). *Post hoc* analysis identified the significant difference between high and low trait EI and serum cortisol response immediately post the treadmill ultramarathon only, $t(10)=-3.2$, $p=0.01$. Although there was no significant difference between high and low trait EI on RPE at a self-selected velocity (Fig 2.A; $p>0.05$), at the controlled velocity of $8km\cdot h^{-1}$ (Fig 2.B), a significant difference in RPE was identified between the high and low trait EI groups (≤0.05) at the 48.3km and 64.4km intervals respectively, $t(10)=2.6$, $p=0.027$ & $t(10)=2.5$, $p=0.032$ (Fig 2.B). There was no difference in fractional utilisation of $\dot{V}O_{2max}$ (*F*) and percentage HRmax ($\%HR_{max}$) between the high and low trait EI groups (p>0,05).

Total mean energy intake during the 80.5km treadmill ultramarathon was 6.68±2.35 mega joules (MJ) and 1588±553 kilocalories (kcal). Macronutrient intake was 37.18±12.6.0 $g\cdot h^{-1}$ carbohydrate (CHO), 2.64±2.0 $g\cdot h^{-1}$ fat and 8.33±1.1 $g\cdot h^{-1}$ protein (PRO). There was no significant difference between nutritional intake between the high and low trait EI groups ($p>0.05$). Exercise-induced BM loss was 2.6±0.97kg ($p<0.001$), which equated to a percentage loss of 3.9±1.32%.

ACCEPTED MANUSCRIPT

ACCEPTED MANUSCRIPT

Discussion

The key findings of this research highlight the physiological and psychological stressors imposed by a treadmill ultramarathon, demonstrated by the expected increase in fatigue and decrease in vigor, leading to the increase in TMD along with an increase in serum cortisol over the course of the treadmill ultramarathon. Contrasting with the hypothesis and previous research[21] participants with a higher trait EI displayed greater post-trial cortisol responses which may suggest the runners are able to push themselves to their physical limits and are better equipped at handling the emotions that accompany physical stress during a treadmill ultramarathon. This is supported by the lower reported RPE and TMD in the high trait EI group (Fig 2). Those with low trait EI had a lower post cortisol response (Fig2. B), which could indicate that the group were less physically stressed. Yet, perceptually the lower trait EI group reported greater RPE as well as elevated TMD scores throughout the treadmill ultramarathon, which potentially indicates higher psychological strain than physiological strain, demonstrated by no difference in *F* and $\%HR_{max}$ between the high and low trait EI groups.

It has been suggested that athletes with higher trait EI may approach sporting competitions with less anxiety, as more of a challenge and are more likely to employ effective coping strategies in response to the stress of the competition[7], as well as better correlate their mood states with optimal performance.[6] Also, a novel proposition may be that the high trait EI group 'enjoy' the challenge of the ultramarathon, which we theorise they use as a tool to satisfy their masochism to derive pleasure from their experienced pain and discomfort of the ultramarathon. Performance times between the two groups in the current study where not significant, which contradicts recent findings from Rubaltelli et al.[10] who showed that half marathon runners with high trait EI ran faster than those with low trait EI. Thus, they are more effective at regulating their emotions and deal with the highs and lows of a distance running event and therefore can effectively manage their pace to complete the distance most efficiently[11].

ACCEPTED MANUSCRIPT

As expected, there was an increase in fatigue and decrease in vigor over the course of the treadmill ultramarathon, as well as a progressive increase in RPE; which is consistent with previous research.[3,24] This is supported by Micklewright et al.[3] who suggested that RPE influences the way in which ultramarathon runners pace themselves rather than being driven by their predetermined performance goals. Both RPE at a self-selected speed and the control speed increased from start to finish, even though overall moving speed and HR decreased (Table 1). These results contradict previous research that demonstrated a decrease in RPE in the latter stages of a 161km ultramarathon, which was attributed to a decrease in running intensity.[25] The comparison of RPE from this study to previous studies must be made with caution as the majority of previous research was conducted in the field during race events,[25] where altitude loss and gain, temperature, and external competition will affect RPE. However, as can be seen from the current study (Table 1), if a lower initial pace is adopted, such as the controlled velocity of 8km·h^{-1}, a lower RPE is likely to displayed, which may have significant performance implications for longer duration ultramarathons.

There was a significant increase in serum cortisol levels at both the halfway and post treadmill ultramarathon distances, but little change in overall mood states, with only the expected decreases in vigor and increase in fatigue. The increase in cortisol may be linked to regulatory factors in maintaining glucose homeostasis and stimulating gluconeogenesis in the liver and shift to fatty acid oxidation.[24,26] An increase in exogenous carbohydrate ingestion has been shown to attenuate increases in cortisol concentrations.[27] However, there was no significant difference between CHO intake between those with high and low trait EI (Table 2), and cannot be attributed to the increase in post cortisol levels in the high trait EI group compared to the low trait EI group. Other factors that may have led to the increase in cortisol concentration could be increased GI distress, with the majority of participants reporting some degree of GI distress, with symptoms ranging from: vomiting, diarrhoea, bloatedness and flatulence. GI distress has previously been reported as one main reason for non-completion of an ultramarathon[5]; these symptoms may also cause significant psychological distress when

ACCEPTED MANUSCRIPT

perceived as uncontrollable factors. The large variability in cortisol response between individuals (Fig 1.B), with a number of participants displaying peak cortisol responses at the halfway distance, which may be explained by adopting a unsustainable running velocity in the first half of the ultramarathon, which can be seen by the decrease in pace in the second half (Table 2), which might have alleviated some of aforementioned mentioned physiological factors.[3-5] It has also been suggested that there is a minimum exercise intensity at or above 60%$\dot{V}O_{2max}$ that is required to elicit a cortisol response.[28] An average intensity of 66±3%$\dot{V}O_{2max}$ was observed in the current study (Table 2), which is sufficient to explain the marked increase in cortisol concentration. There was no significant difference in intensity between high and low trait EI groups with an average %$\dot{V}O_{2max}$ of 68±8.8 and 65.2±4.5, respectively (Table 2). It could be proposed that the extreme physiological exertion required during an ultramarathon may be the main driver in the elevation of serum cortisol.

Fluctuations in mood and motivation during ultramarathons are worth exploring in greater detail, as this could influence dropout rates commonly observed in ultramarathons. In the present study, there was an 85% completion rate, despite a small sample size; this is higher than finish rates typically observed in the field, which range between 51 to 88%.[29] It should be noted however, that the participants in this study all volunteered to take part, which may indicate that they were already familiar with coping with the stressors of an ultramarathon, therefore future studies should endeavour to investigate ‘first time’ ultramarathon runners compared with more experienced runners.

Lastly, from the controlled laboratory ranges of cortisol, mood states relating to trait EI identified in the current study, further ecological validation in a race setting is warranted. Future research should also investigate the coping strategies ultramarathon runners employ, through combining a mixed methods approach, such as using interviewing and/or self-recorded in-event audio diaries[30], with an objective physiological marker of stress, such as cortisol and testosterone, along with assessing pleasant emotions, motivations for taking part and performance goals. This could help the development of physiological and psychological coping strategies and guidelines to aid better performance in ultramarathon events.

ACCEPTED MANUSCRIPT

ACCEPTED MANUSCRIPT

Conclusion

The 80.5km treadmill ultramarathon elicited a significant increase in serum cortisol, which was significantly greater in those with a higher trait EI. Those individuals with higher trait EI were more effective at managing their mood, with little change in their TMD and perceived effort compared to those with lower trait EI. As there was no difference in performance times between high and low trait EI group, the increase in post cortisol in the high trait EI group could be attributed to a slightly higher work rate (*F*), and a more evenly paced running velocity over the duration of the event, demonstrating the higher trait EI group were more able to deal with the psychological burden imposed by the ultramarathon.

Practical Implications

- An athlete's personal traits and emotions may impact perceived exertion, mood states and physiological markers of stress when taking part in ultramarathons.
- Coaches and athletes should aim to set realistic and manageable pace setting goals in order to effectively manage mood and perceived exertion throughout ultramarathons.
- Individuals with a higher trait EI appear to cope better with the discomfort they experience which we theorise they use as a tool to satisfy their masochism to derive pleasure from their experienced pain and discomfort of the ultramarathon

Acknowledgements
The authors would like to thank all the participants for their time and effort in taking part in this extreme challenge, as well as Anna Kosciuk for her help during the data collection process.

ACCEPTED MANUSCRIPT

ACCEPTED MANUSCRIPT

References

1. Hoffman MD, Fogard K. Factors related to successful completion of a 161-km ultramarathon. *Int J Sports Physiol Perform* 2011; 6(1):25-37.

2. Knechtle B. Ultramarathon runners: nature or nurture? *Int J Sports Physiol Perform* 2012; 7(4):310-312.

3. Micklewright D, Papadopoulou E, Parry D, et al. Perceived exertion influences pacing among ultramarathon runners but post-race mood change is associated with performance expectancy. *South African J Sports Med* 2009; 21(4).

4. Lane AM, Wilson M. Emotions and trait emotional intelligence among ultra-endurance runners. *J Sci Med Sport* 2011; 14(4):358-362.

5. Stuempfle KJ, Hoffman MD. Gastrointestinal distress is common during a 161-km ultramarathon. *J Sports Sci* 2015; 33(17):1814-1821.

6. Lane A, Thelwell R, Devonport T. Emotional intelligence and mood states associated with optimal performance. *E J Appl Psychol* 2009; 5(1):67-73.

7. Laborde S, Lautenbach F, Allen MS, et al. The role of trait emotional intelligence in emotion regulation and performance under pressure. *Pers Individ Dif* 2014; 57:43-47.

8. Wagstaff CR. Emotion regulation and sport performance. *J Sport Exerc Psychol* 2014; 36(4):401-412.

9. Petrides KV, Pita R, Kokkinaki F. The location of trait emotional intelligence in personality factor space. *Br J Psychol* 2007; 98(2):273-289.

10. Rubaltelli E, Agnoli S, Leo I. Emotional intelligence impact on half marathon finish times. *Pers Individ Dif* 2018; 128:107-112.

11. Zizzi S, Deaner H, Hirschhorn D. The relationship between emotional intelligence and performance among college basketball players. *J Appl Sport Psychol* 2003; 15(3):262-269.

12. Tharion WJ, Strowman SR, Rauch TM. Profile and changes in moods of ultramarathoners. *J Appl Sport Psychol* 1988; 10(2):229-235.

13. Bahrke MS, Morgan WP. Anxiety reduction following exercise and meditation. *Cognit Ther Res* 1978; 2(4):323-333.

14. Borg GA. Psychophysical bases of perceived exertion. *Med Sci Sports Exerc* 1982; 14(5):377-381.

15. Powell J, DiLeo T, Roberge R, et al. Salivary and serum cortisol levels during recovery from intense exercise and prolonged, moderate exercise. *Biol Sport* 2015; 32(2):91-95.

16. Glaser R, Kiecolt-Glaser JK. Stress-induced immune dysfunction: implications for health. *Nat Rev Immunol* 2005; 5(3):243.

ACCEPTED MANUSCRIPT

ACCEPTED MANUSCRIPT

17. Laborde S, You M, Dosseville F, et al. Culture, individual differences, and situation: Influence on coping in French and Chinese table tennis players. *Eur J Sport Sci* 2012; 12(3):255-261.

18. Gimenez P, Kerherve H, Messonnier LA, et al. Changes in the energy cost of running during a 24-h treadmill exercise. *Med Sci Sports Exerc* 2013; 45(9):1807-1813.

19. Chan S, Debono M. Replication of cortisol circadian rhythm: new advances in hydrocortisone replacement therapy. *Ther Adv Endocrinol Metab* 2010; 1(3):129-138.

20. Schutte NS, Malouff JM, Hall LE, et al. Development and validation of a measure of emotional intelligence. *Pers Individ Dif* 1998; 25(2):167-177.

21. Mikolajczak M, Roy E, Luminet O, et al. The moderating impact of emotional intelligence on free cortisol responses to stress. *Psychoneuroendocrinology* 2007; 32(8-10):1000-1012.

22. Terry PC, Lane AM, Fogarty GJ. Construct validity of the Profile of Mood States—Adolescents for use with adults. *Psychol Sport Exerc* 2003; 4(2):125-139.

23. Milton K, Lane A, Terry P. Personality does not influence exercise-induced mood enhancement among female exercisers. *J Sports Med Phys Fitness* 2005; 45(2):208.

24. Utter AC, Kang J, Nieman DC, et al. Ratings of perceived exertion throughout an ultramarathon during carbohydrate ingestion. *Percept Mot Skills* 2003; 97(1):175-184.

25. Utter AC, Nieman DC, Kang J, et al. Quercetin does not affect rating of perceived exertion in athletes during the Western States endurance run. *Res Sports Med* 2009; 17(2):71-83.

26. Howe CC, Alshehri A, Muggeridge D, et al. Untargeted metabolomics profiling of an 80.5 km simulated treadmill ultramarathon. *Metabolites* 2018; 8(1):14.

27. Nieman DC, Nehlsen-Cannarella SL, Fagoaga OR, et al. Influence of mode and carbohydrate on the cytokine response to heavy exertion. *Med Sci Sports Exerc* 1998; 30(5):671-678.

28. Hill E, Zack E, Battaglini C, et al. Exercise and circulating cortisol levels: the intensity threshold effect. *J Endocrinol Invest* 2008; 31(7):587-591.

29. Hoffman MD, Wegelin JA. The Western States 100-Mile Endurance Run: participation and performance trends. *Med Sci Sports Exerc* 2009; 41(12):2191-2198.

30. Holt NL, Lee H, Kim Y, et al. Exploring experiences of running an ultramarathon. *The Sport Psychologist* 2014; 28(1):22-35.

ACCEPTED MANUSCRIPT

ACCEPTED MANUSCRIPT

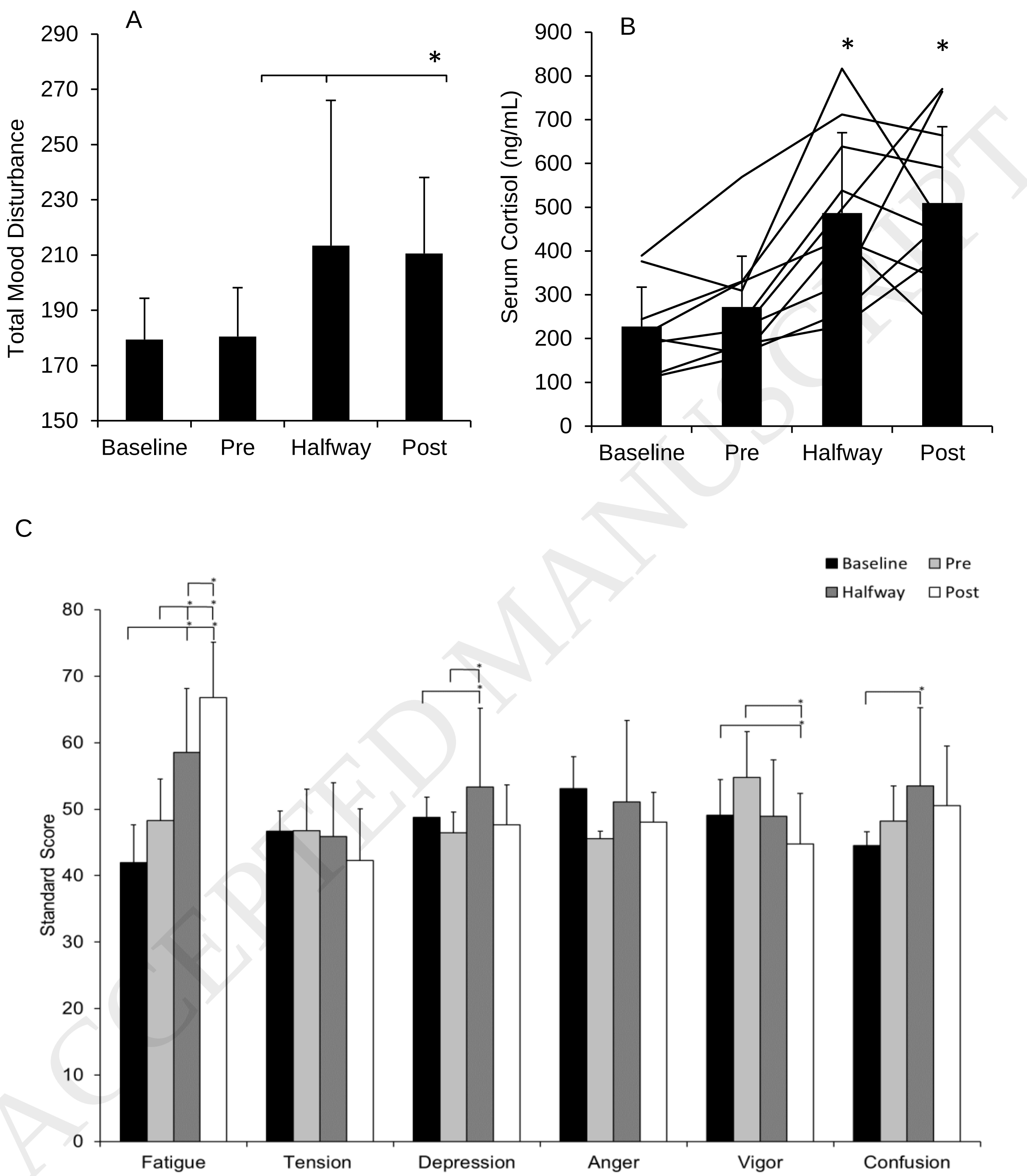

Fig. 1. Group mean data (n=12) (A) TMD scores, (B) Serum cortisol response *(Solid bars represents group mean ± SD, lines represent individual participant responses)* * indicates

ACCEPTED MANUSCRIPT

significant difference from pre values (p<0.05). (C) Baseline, Pre, Halfway & Post BRUMS mood sub scales (mean ± SD).

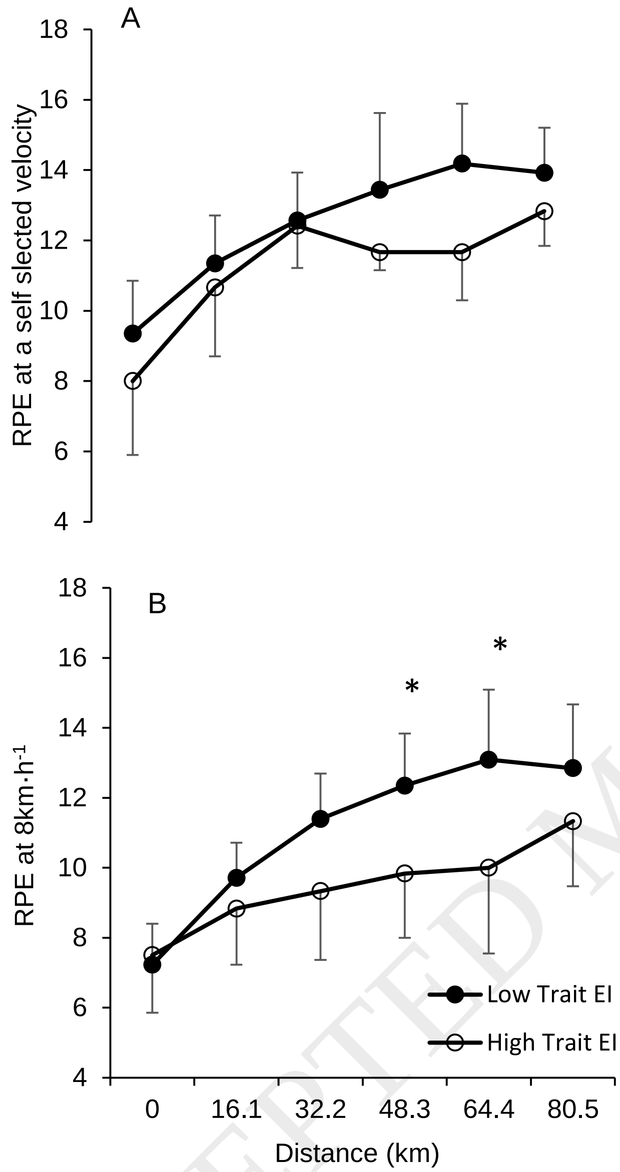

Fig 2. Comparison between high and low trait EI groups; (A) RPE at a self-selected running velocity, (B) RPE at control velocity (8km·h^{-1}). * indicates significant difference between high & low trait EI groups (p≤0.05).

ACCEPTED MANUSCRIPT

ACCEPTED MANUSCRIPT

Table 1. Descriptive variables from 80.5km time trail measured at 16.1km intervals at a self-selected velocity & RPE at controlled velocity

Variable	**Start**	**16.1km**	**32.2km**	**48.3km**	**64.4km**	**80.5km**	**Mean ± SD**
Total Trial Time (mins)	n/a	93±9	193±20	306±33	434±54	540±74	**540±74**
Treadmill Velocity ($km \cdot h^{-1}$)	11.1±1.6	11.2±1.1	10.6±1.4	10.0±1.5$^{\#}$	9.5±1.7$^{\#}$	9.4±1.6$^{*\#}$	**10.3±1.3**
Body Mass (kg)	68.9±7.5	67.7±7.4	67.1±7.2	66.7±7.0	66.5±7.1	66.3±7.0	**67.2±0.97**
$\dot{V}O_2$ ($ml \cdot kg^{-1} \cdot min^{-1}$)	40.5±3.6	41.9±3.5	41.7±3.7	40.4±4.8	39.5±7.0	38.3±6.4	**40.4.6±1.35**
F (%VO_{2max})	68.3±6.3	69.6±7.3	68.6±7.1	66.0±8.2	64.4±11.5	62.2±10.5	**66.5±2.9**
HR ($beats \cdot min^{-1}$)	146±14	156±15	158±12	156±12	149±13	146±15	**152±5**
$\dot{V}_E$ ($L \cdot min^{-1}$)	71.1±10.6	73.6±10.0	73.4±9.6	69.2±12.4	68.1±12.3	68.7±12.4	**70.7±2.4**
RPE (at self-selected velocity)	9.0±2.0	11.0±2.0*	12.0±1.0*	13.0±2.0*	13.0±2.0*	14.0±1.0*	**12.0±2.0**
RPE (8 $km \cdot h^{-1}$)	7.0±1.0	9.0±1.0*	10.0±2.0*	11.0±2.0*	12.0±3.0*	12.0±2.0*	**10.0±2.0**

$\dot{V}O_{2max}$: maximal oxygen uptake capacity, *F:* fractional utilisation of $\dot{V}O_{2max}$, HR: heart rate, $\dot{V}_E$: minute ventilation, RPE: Ratings of perceived exertion, body mass (mean ± SD) indicates pre-to-post difference. (significant difference ($p<0.05$) from * the start of the 80.5km trial; and both $^{\#}$ 16.1km and 32.2km).

ACCEPTED MANUSCRIPT

Table 2. Descriptive variables and comparisons between high and low trait EI groups.

Variables	**Low Trait EI (n=6)**	**High Trait (n=6)**	**P value**
$\dot{V}O_{2max}$ (ml·kg^{-1}·min^{-1})	62.2±3.7	59.6±4.4	0.29
Run Time (mins)	517±55	486±75	0.44
Run Time Velocity (km·h^{-1})	9.5±1.1	10.1±1.6	0.43
Elapsed Time (mins)	569±82	525±86	0.38
Elapsed Velocity (km·h^{-1})	8.8±1.1	9.4±1.5	0.44
Velocity 1st half (km·h^{-1})	10.3±1.2	10.4±1.2	0.39
Velocity 2nd half (km·h^{-1})	7.7±1.03	8.6±1.8	0.85
Decrease in velocity (km·h^{-1})	2.6±0.4	1.8±1.0	0.29
Baseline cortisol (ng/mL)	204.9±98.8	250.7±70.5	0.38
Pre cortisol (ng/mL)	235.3±75.1	308.6±134.20	0.27
Halfway cortisol (ng/mL)	441.1±210.4	532.8±134.3	0.39
Post cortisol (ng/mL)	396.2±109.1	623.2±134.5	0.01*
Baseline TMD	186.4±13.1	172.5±14.2	0.93
Pre TMD	186.2±15.6	174.7±19.2	0.11
Halfway TMD	243.6±54.8	183.3±30.0	0.28
Post TMD	218.3±18.0	202.8±34.8	0.04*
Total Energy Intake (MJ)	7.2±2.1	6.2±2.7	0.72
Total Energy Intake (Kcal)	1717±476	1460±637	0.46
Total CHO intake (g)	327.7±99.4	298.1±135.7	0.11
CHO (g·h^{-1})	38.6±12.4	35.8±13.8	0.68
F(%$\dot{V}O_{2max}$)	65.2±4.5	68.0±8.9	0.45
%HR_{max}	80.0±3.0	80.0±2.0	0.89

$\dot{V}O_{2max}$: maximal oxygen uptake capacity, TMD: total mood disturbance, CHO: carbohydrate *F:* fractional utilisation of $\dot{V}O_{2max}$, (mean ± SD) indicates pre-to-post difference. (*significant difference ($p<0.05$).