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Running title: Risk, Pacing & Performance

Abstract

Purpose: To examine risk-taking and risk-perception associations with perceived exertion, pacing and performance in athletes. Methods: Two experiments were conducted in which risk-perception was assessed using the domain-specific risk-taking (DOSPERT) scale in 20 novice cyclists (Experiment 1) and 32 experienced ultra-marathon runners (Experiment 2). In Experiment 1, participants predicted their pace and then performed a 5 km maximum effort cycling time-trial on a calibrated KingCycle mounted bicycle. Split-times and perceived exertion were recorded every kilometer. In experiment 2, each participant predicted their split times before running a 100 km ultra-marathon. Split-times and perceived exertion were recorded at 7 check-points. In both experiments, higher and lower risk-perception groups were created using median split of DOSPERT scores. Results: In experiment 1, pace during the first km was faster among lower compared to higher risk-perceivers, t(18)=2.0 P=0.03, and faster among higher compared lower risk-takers, t(18)=2.2 P=0.02. Actual pace was slower than predicted pace during the first km in both the higher risk perceivers, t(9)=-4.2 P=0.001, and lower risk-perceivers, t(9)=-1.8 P=0.049. In experiment 2, pace during the first 36 km was faster among lower compared to higher risk-perceivers, t(16)=2.0 P=0.03. Irrespective of risk-perception group, actual pace was slower than predicted pace during the first 18 km, t(16)=8.9 P<0.001, and from 18 to 36 km, t(16)=4.0 P<0.001. In both experiments there was no difference in performance between higher and lower risk-perception groups. Conclusions: Initial pace is associated with an individual's perception of risk, with low perceptions of risk being associated with a faster starting pace. Large differences between predicted and actual pace suggests the performance template lacks accuracy, perhaps indicating greater reliance on momentary pacing decisions rather than pre-planned strategy.

Key Words: Cycling; Running; Marathon; Perceived Exertion; Emotional Intelligence

Introduction

Athletic pacing has been described as the way power output, work or energy expenditure is controlled or distributed to complete an event in the fastest possible time, having utilized all available resources (11,16,19). Different types of pacing strategy have been described, as observed in exercise tasks of varying durations (1,12). For example, in events lasting less than a minute an all out pacing strategy is optimal (11), but for longer events conserving energy is important (1,33). A negative strategy, involving a slow start and gradually increasing speed, is the most conservative and least risky approach to pacing an endurance event, but probably does not produce the best performance (2,15,36). In contrast, positive fast start strategies deplete metabolic reserves too early (36), are rarely successful (1,12) and indicate either a lack of experience or poor anticipatory mechanisms (23). Parabolic strategy, comprising moderate starting speed, slower mid-section and fast finish, often results in faster completion of endurance events (1) but athletes must make a risk-based judgements about the maximum speed they can tolerate at the beginning without compromising performance later in the task.

A variety of explanations of how pace is controlled have been put forward, all of which have included rating of perceived exertion (RPE) as a psychophysiological cue in effort regulation (12,14,18,33,38). Perceptions of exertion or fatigue are thought to arise from integrated afferent feedback and as such represent a global conscious awareness of the physiological state of the body (32-34). Slightly different explanations have been put forward about how RPE is used to regulate pace. In the template-matching model (38), pace is modified according to how well experienced RPE compares against expected RPE, given the remaining distance to the endpoint. This model is in part based upon previous findings showing how pace is modified in order to maintain a scalar linear increase in RPE whereby peak RPE coincides with the endpoint (14). In the estimated time-limit model (18), a pace is settled upon according to the amount of time such a pace can be maintained, given the corresponding RPE and the estimated time required to reach the endpoint. While both of these models take into account the endpoint, a third model has placed particular emphasis on duration-based risk-evaluation whereby pacing decisions arise from the product of momentary RPE and the proportion of the task remaining, a metric referred to as hazard score (12). What is explicitly recognised in this model is the riskiness of adopting a pace with a corresponding high RPE at the beginning of an event.

In recent years, numerous factors have been found to influence pacing behaviour among athletes. These have included physiological factors such as core temperature, muscle acidosis, oxygen uptake, and carbohydrate availability (39). Pace is also affected by extrinsic factors such as ambient temperature (35), wind speed (4), the presence of competitors (10), strategic decisions (27), optic flow (26,24) and the nature of performance feedback information (23). A growing area of understanding is how individual differences influence pacing behaviour, and in this respect there has been some work on cognitive development and pacing (9,22), as well as many studies on the effect of prior experience on pacing (3,15-17,23). One type of difference that has not yet been investigated is how pacing is influenced by individual perceptions of risk and an individual's propensity to take risks. Given the emphasis of risk in the hazard score model (12), individual risk-perception and risk-taking traits maybe important determinants of early pace, especially in medium or long-duration events where an excessively fast start can have a detrimental effect on overall performance (1,12). Risk-perception refers to an individuals appraisal of risk, and risk-taking refers to an individual's tendency to take risks, both of which can vary between different situations (6).

It is fairly well established that decisions involving risk are not just based upon a rational objective analysis of the circumstances, referred to as risk-as-analysis, but are also influenced by emotions associated with past experience, referred to as risk-as-feelings (31). An athlete, in deciding upon an initial pace, might use the risk-as-analysis approach by drawing upon various sources of available information such as knowledge of the endpoint, course terrain, other competitor behaviour, ambient temperature and so on. Equally an athlete's pacing decisions might be informed by emotional experience, perhaps associated with feelings of exertion, excitement, anxiety or other forms of affect typically experienced before, during or after athletic events (14,23,25,32). As such, an athlete's emotional intelligence, as defined by an ability to recognise, understand, regulate and utilise their emotions (30), may have an important role in risk-based pacing decisions. An athlete's sensitivity to perceive or feel changes in effort, as indicated by their RPE, may also be related to their emotional intelligence, particularly their general ability to recognise and understand emotions. Since RPE has previously been likened to an emotion (32,33), it might be expected that those with greater emotional intelligence might be particularly sensitive to changes in RPE. Furthermore, given the emphasis placed on RPE as a determinant of pace (12,14,32,33,38), it might also be expected that greater RPE sensitivity results among those with greater emotional intelligence cause them to reflect upon and perhaps alter their pace more frequently.

Of further interest is how an athletes perception of risk, risk-taking traits and emotional intelligence influences the extent to which they are willing to deviate their pace from a previously planned pacing strategy. On the one hand adopting a pacing strategy that differs from one supported through previous experience does constitute a risk yet, on the other hand, being unwilling to adapt a planned pacing strategy, perhaps in response to changing environmental conditions or competitor behaviour, is also risky. Understanding how actual pace differs from planned pace may provide further insight about how individual differences in risk perception and emotional intelligence influence strategic pacing behaviour during events.

In this paper we attempted to investigate how individual riskiness traits influence perceived exertion, pacing and performance. We also compared conscious pacing expectations of the participants with their actual pacing profile. Two separate experiments are presented. In experiment 1 pace, perceived exertion and performance were measured during a 5 km laboratory simulated time trial among novice cyclists with lower and higher-risk perceptions and risk-taking traits. Experiment 2 examined the effect of risk-perception and emotional intelligence upon pacing, perceived exertion and performance but, in contrast to experiment 1, this was among experienced ultramarathon runners. While we acknowledge that 5 km time-trial cycling and ultramarathon running are very different, we believe that presenting and discussing both studies in a single paper is helpful in the generalization of our findings about the association between individual perceptions of risk and pacing strategy. In experiment 1 we hypothesised that those with a greater tendency to perceive situations as risky, and those who tend to take less risky decisions, would adopt a more conservative relative starting pace compared to lower risk-perceivers and higher risk-takers respectively. In experiment 2 we hypothesised that those with a greater tendency to perceive situations as risky would adopt a slower relative starting pace compared to lower risk-perceivers. We also hypothesised that RPE and pace would differ between lower and higher emotional intelligence groups, although we are unable to predict in which direction these differences will be.

EXPERIMENT 1

The effect of risk-perception and risk-taking on pacing strategy
among novice time-trial cyclists

Methods

Participants

Twenty participants (female=5, male=15) were recruited from the University of Essex (Age 20.9 ± 1.1 years, stature 176.9 ± 8.5 cm and body mass 79.6 ± 12.2 kg). All participants were healthy and participated in moderate physical activity of at least thirty-minutes, three times per week. Although they could ride a bicycle, all participants were novice cyclists in the sense that they had not previously been members of a cycling club, participated in time-trialling or any other forms of competitive cycling. Each participant provided written informed consent to take part in this study, which was approved by the University of Essex ethics committee.

Design

A two-way between and within-subjects experimental design was used. All participants completed a risk-taking and risk-perception questionnaire (6), the results of which were used to split participants into higher and lower risk-takers and higher and lower risk-perceivers (between-subjects risk factor). Pacing predictions were measured in participants before actually performing a 5 km laboratory-based cycling time-trial (within-subjects prediction factor). Participants provided a rating of perceived exertion (7) every kilometer.

Risk Perception and Risk Taking Measurements

Perceptions of risk and risk-taking traits were measured using the revised domain-specific risk-taking scale (DOSPERT) (6). The DOSPERT comprises two 30-items scales, one for risk-taking and one for risk-perception, the responses to which are quantified using a 7-point likert scale. The possible range of DOSPERT scores is 30-210 with a high risk perception score indicates greater tendencies to perceive situations as risky, and a high risk taking score indicating greater tendencies to take risks. English population normative scores for risk-perception is 121 ± 7.3 and for risk-taking is 116 ± 7.3 (6). All participants completed the DOSPERT prior to making their pacing predictions and performing the cycling time trial.

Pacing Predictions and 5 km Time Trial Cycling Ergometry

Prior to performing the cycling time trial, all participants were asked to predict what pace they believed they would adopt during each kilometer segment. The predictions were measured using a Microsoft Excel macro in which participants were free to alter parameters of a pacing graph. Similar to the graphs presented in Figure 1, participants were presented with an average speed line and then for each kilometer segment they were able to adjust the percentage of pacing deviation from average speed, either faster or slower, until they were happy with the overall shape of the pacing profile. The macro was programmed such that it would not accept a pacing profile that did not mathematically balance exactly to the average speed line and a numerical indicator was provided so that participants could see how far away from balancing their predictions they were. Essentially the macro ensured that across the whole trial the predictions had an equal number of percentage points above and below the average speed line. While the pacing prediction task was fully explained to participants, no advice on pacing strategy was given. Participants were permitted to use the prediction macro with no time restrictions until they were content with the predicted pacing profile they had made. A percent deviation from average speed prediction task was considered more appropriate for novice time trial cyclists than absolute speed predictions, also serving to facilitate direct comparison with normalised actual pacing data.

Time Trial Cycling Ergometry

After completing the prediction task participants were asked to lay supine in a quite room for 15 minutes and resting heart rate was measured using a Polar 610i heart rate monitor (Polar, Finland). All participants completed a 5-minute warm-up at 80% heart rate reserve and 5 km time trial using a laboratory racing bicycle mounted on a calibrated Kingcycle air-braked cycling ergometer (EDS Portaprompt Ltd., High Wycombe, UK). Handlebar position and seat height was adjusted to suit each participant. During both the warm-up and time-trial participants were permitted to self-select gearing and cadence. Cycling speed and elapsed distance were displayed to participants using a calibrated Revolution Velocity 20 wireless cycle computer (Revolution Velocity, Manchester). Given that novice cyclists were used in this study the secondary purpose of the warm-up was of familiarisation in the use of the bicycle, gears and cycling ergometry. Once the warm-up was complete participants were given the opportunity to ask questions about the use of the bicycle or any other experimental procedures. All participants were then instructed to complete the cycling time trial in their fastest possible time. Participants were not provided with any pacing or performance guidance, advice or instructions. Elapsed time was recorded each kilometer from which average cycling speed was calculated.

Perceived Exertion and Hazard Score Measurements

At every kilometre during each time trial, participants were asked to provide an overall rating of perceived exertion using the Borg 6-20 RPE scale (7). Prior to testing, each participant was familiarised with the RPE scale, which was administered in accordance with published standardised instructions (7). As previously described (12), hazard score was calculated for each kilometer segment as RPE multiplied by the percentage of distance remaining.

Data Analysis

Lower and higher risk taking and risk perception groups were created by a median split of DOSPERT scores. Risk-taking and risk-perception group differences in performance, expressed as average cycling speed, were analysed using independent samples *t*-tests.Between-subject variance in cycling speed was normalised by calculating kilometer-by-kilometer percentage deviation from overall average cycling speed. Two-way between and within-subjects ANOVA's were used to analyse kilometer segment differences in pace, RPE and hazard score between the lower and higher risk-taking and risk-perception groups. Two-way within-subjects ANOVA's were used to make comparisons between predicted and actual pace. Because pace data was normalised the sum of all segment point always equalled zero therefore there were no group main effects. Significant risk-perception and risk-taking group pacing interactions were followed up using one-tailed independent-samples *t*-tests. Prediction-by-segment interactions were followed up using one-tailed paired-samples t-tests. All results are expressed as means ± one standard deviation and effect sizes as eta squared (η^2). An alpha level of 0.05 was used to indicate statistical significance.

Results

Risk-perception and Risk-Taking Scores

Total DOSPERT scores for the lower and higher risk-perception groups were 96.2 ± 14.5 and 131.8 ± 7.4 respectively. DOSPERT scores for lower and higher risk-taking groups were 99.5 ± 9.6 and 127.9 ± 10.0 respectively.

Performance and Pacing

There was no difference in average cycling speed between lower and higher risk-perceivers (29.9 ± 3.8 $km.hr^{-1}$ vs. 29.3 ± 5.4 $km.hr^{-1}$, t_{18}=-0.3, $P = 0.79$, $\eta^2 < 0.01$) or lower and higher risk-takers (28.9 ± 5.5 $km.hr^{-1}$ vs. 30.3 ± 3.6 $km.hr^{-1}$, t_{18}=-0.6, $P = 0.53$, $\eta^2 = 0.02$).

For risk perception, two-way within and between-subjects ANOVA's revealed a risk-perception group-by-segment interaction for pace ($F_{4,72}$=2.7, P=0.035, η^2=0.08) as well as a segment main effect. ($F_{4,72}$=13.0, P<0.001, η^2=0.39). The interaction indicates that the kilometre-by-kilometer changes in pace differed between lower and higher risk-perception groups, and post-hoc one-tailed independent samples *t*-tests which found a slower relative starting pace among the higher risk-perception group (Figure 1A). For risk-taking there was a segment main effect for pace ($F_{4,72}$=12.8, P<0.001, η^2=0.39) and, although there was no group-by-segment interaction ($F_{4,72}$=2.3, P=0.065, η^2=0.07), it did approach significance (Figure 1B). An association was found between deviation of pace from average speed during the first kilometre and risk perception (r_{20}=-0.457, P=0.022), presented in Figure 1C, and with risk-taking (r_{20}=-0.426, P=0.03), presented in Figure 1D.

Ratings of Perceived Exertion and Hazard Score

There was no risk-perception group-by-segment interaction for RPE ($F_{4,72}$=0.2, P=0.95, η^2<0.01) and no group main effect ($F_{1,18}$=2.7, P=0.12, η^2=0.13) but there was a segment main effect ($F_{4,72}$=95, P<0.001, η^2=0.84), meaning that regardless of risk-perception group RPE increased during the time trial (Figure 2A). There was no risk-perception group-by-segment interaction for hazard score ($F_{4,72}$=0.8, P=0.54, η^2=0.01) and no group main effect ($F_{1,18}$=2.6, P=0.13, η^2=0.12) but there was a segment main effect ($F_{4,72}$=707, P<0.001, η^2=0.97),), meaning that regardless of risk-perception group, hazard score decreased during the time trial (Figure 2B).

There was no risk-taking group-by-segment interaction for RPE ($F_{4,72}$=0.1, P=0.98, η^2<0.01) but there was a group main effect ($F_{1,18}$=5.9, P=0.026, η^2=0.25) and a segment main effect ($F_{4,72}$=95, P<0.001, η^2=0.84), meaning that although the lower risk-takers had lower average RPE scores (group main effect), the pattern of increasing RPE throughout the time trial was the same between lower and higher risk-taking groups (segment main effect) (Figure 2C). There was no risk-taking group-by-segment interaction for hazard score ($F_{4,72}$=1.1, P=0.36, η^2<0.01) but there was a group main effect ($F_{1,18}$=4.8, P=0.042, η^2=0.21) and a segment main effect ($F_{4,72}$=720, P<0.001, η^2=0.97)), meaning that although the lower risk-takers had lower average hazard scores (group main effect), the pattern of decreasing RPE throughout the time trial was the same between lower and higher risk-taking groups (segment main effect) (Figure 2D).

Actual vs. Predicted Pacing

Two-way within-subjects ANOVAs were used to compare kilometer-by-kilometer changes in pace (segment factor) between predicted and actual pace (prediction factor). For all subjects combined there was a prediction-by-segment interaction ($F_{4,76}$=10.4, P<0.001, η^2=0.29) as well as a segment main effect ($F_{4,76}$=7.2, P<0.001, η^2=0.24). Among lower risk-perceivers there was a prediction-by-segment interaction ($F_{4,36}$=3.2, P=0.025, η^2=0.21) but no segment main effect ($F_{4,36}$=1.7, P=0.16, η^2=0.20). Among higher risk-perceivers there was a prediction-by-segment interaction ($F_{4,36}$=8.2, P<0.001, η^2=0.33) and a segment main effect ($F_{4,36}$=9.7, P<0.001, η^2=0.30). Among lower risk-takers there was a prediction-by-segment interaction ($F_{4,36}$=7.8, P<0.001, η^2=0.36) and a segment main effect ($F_{4,36}$=6.6, P<0.001, η^2=0.23). Among higher risk-takers there was a prediction-by-segment interaction ($F_{4,36}$=3.0, P=0.03, η^2=0.18) and a segment main effect ($F_{4,36}$=2.7, P=0.04, η^2=0.28). Where interactions are reported this indicates kilometre-by-kilometer differences between predicted and actual pace. The exact nature of these differences were examined using post-hoc one-tailed paired-samples t-tests and are presented in Figures 3A-E.

EXPERIMENT 2

The Effect of Risk-Perception and Emotional Intelligence on Pacing Strategy among Experienced Ultramarathon Runners

Methods

Participants

Thirty-four participants (female=2, male=32) were recruited for this study from the field of runners participating in the Stour Valley Path 100 km ultramarathon race (SVP100). Mean ± 1 SD age, stature and body mass were 39.9 ± 7.6 years, 178.4 ± 7.1 cm and 74.8 ± 9.2 kg. All participants were experienced endurance runners who during a two year period prior to the study had participated in 3.8 ± 5.1 competitive marathons, 10.1 ± 17.4 competitive runs shorter than marathon distance, and 5.6 ± 8.9 ultramarathons over an average distance of 92.9 ± 39.9 km. The large SD values for competitive running history were due to a minority of runners competing in greater than 20 events in the previous two years resulting in positively skewed data distribution for marathons (skewness=2.1, SE=0.4), ultramarathons (skewness=2.9, SE=0.4) and runs shorter than marathon distance (skewness=4.1, SE=0.4), noting that for normally distributed data skewness ≅ 1. During the three-month period preceding the study participants ran on average 4.5 ± 1.5 times per week covering an average weekly distance of 61.4 ± 23.0 km. Each participant provided written informed consent to take part in this study, which was approved by the University of Essex ethics committee.

Design

Similar to experiment 1, a two-way between and within-subjects experimental design was used. All participants completed the risk-perception element of DOSPERT (6) as well as an emotional intelligence questionnaire (SEIS) (30). In this second experiment, emotional intelligence measurements were added because, after considering the lack of differences in RPE and hazard score between the risk groups in experiment one, we speculated that the way individuals perceive and feel effort might be related to their general ability to recognise, understand, regulate emotions. In order to minimise questionnaire fatigue, participants were not asked to complete the risk-taking element of DOSPERT (6), especially since the covariance with risk-perception is very high. Furthermore it was felt that risk-perception, as a measure of cognition, would yield stronger explanatory data about the influence of psychological processes on pacing, compared to risk-taking which is a measure of behaviour. Emotional intelligence was measured to investigate whether an athlete's ability to recognise, understand, regulate and utilise their emotions has any bearing on their risk-based pacing decisions. Median split of DOSPERT and SEIS results were used to create higher and lower risk-perception groups, and higher and lower emotional intelligence groups (between-subjects factors). All runners were asked to predict split times for each check-point prior to running the SVP100, and the predictions were later compared with actual split times (within-subjects prediction factor). A rating of perceived exertion was collected at each checkpoint from all participant runners.

Risk Perception and Emotional Intelligence Measurements

Perceptions of risk were measured using the revised domain-specific risk-taking scale (DOSPERT) (6), identical to the method described in experiment 1. Emotional intelligence was measured using the Schutte Emotional Intelligence Scale (SEIS) (30). The SEIS comprises 33-items, the responses to which are quantified using a 5-point likert scale. The possible range of SEIS scores is 33-195, whereby a higher score represents greater emotional intelligence. All participants completed both the DOSPERT and SEIS prior to running in the SVP100.

Pacing Predictions, Ultramarathon Performance

Prior to performing the SVP100 ultramarathon, participants were asked to carefully examine the course profile and predict their split times for each check-point (CP). The predicted split times were used to calculate predicted average running speed for the whole race in relation to which predicted running speed for each segment was expressed as a percentage deviation. In total there were six CP's throughout the race before the finish point (CP1=18.7 km, CP2=36.5 km, CP3=52.3 km, CP4=66.2 km, CP5=79.0 km, CP6=91.9 km and finish point=99.0 km). The distance between CP's were as follows: Start-CP1=18.7 km, CP1-2=17.8 km, CP2-3=15.7 km, CP3-4=14.0 km, CP4-5=12.7 km, CP5-6=13.0 km, CP6-finish=7.1 km. A researcher was positioned at each CP and recorded the time at which each runner arrived. Check-point arrival times were later used to calculate split running times, average speeds for each segment.

Perceived Exertion and Hazard Score Measurements

At each CP, each runner provided a rating of perceived exertion using the Borg 6-20 RPE scale (7). Prior to the race, each runner was familiarised with the RPE scale, which was administered in accordance with published standardised instructions (7). As previously described (12), hazard score was calculated for each CP as RPE multiplied by the percentage of distance remaining.

Data Analysis

A median split of DOSPERT score and SEIS scores were used to create lower and higher risk perception and emotional intelligence groups respectively. Between-subject variance in segment running speeds were normalised by expressing them as percentage deviations from average running speed for the whole race. Main effects, interactions and post-hoc tests for race segments, risk-perception group and emotional intelligence group for pace, RPE and hazard score were all analysed using exactly the same statistical methods as those described in experiment one. All results are expressed as means ± one standard deviation and effect sizes as partial eta squared (η^2). An alpha level of 0.05 was used to indicate statistical significance to test the first two hypotheses, but 0.025 was used for the third two-tailed hypothesis.

Results

Total DOSPERT scores for the lower and higher risk-perception groups were 111.5±13.9 and 141.9±8.0 respectively. Total EIQ scores for lower and higher emotional intelligence groups were 107.4±8.9 and 127.3±6.8 respectively. The ultramarathon runners had greater perceptions of risk compared to the 5 km time trial cyclists reported in experiment 1 (126.3±22.5 vs. 114.0±21.4, t_{52}=2.0, P=0.027, η^2=0.01).

Risk Perception Group Comparisons of Performance and Emotional Intelligence

Average completion time was 822±66 mins for the lower risk-perceivers and 800±80 mins for the higher risk-perceivers. There was no difference in average running speed between lower and higher risk-perceivers (7.3±0.7 $km.hr^{-1}$ vs. 7.5±0.8 $km.hr^{-1}$, t_{32}=-0.9, P=0.4, η^2 =0.01). However, lower risk-perceivers exhibited lower emotional intelligence compared to the higher risk-perceivers (76.3±10.5 vs. 85.1±13.7 respectively, t_{32}=-2.1, P=0.022, η^2=0.12).

Risk Perception and Emotional Intelligence Group Comparisons of Pace

Two-way within and between-subjects ANOVA's showed a risk-perception a group-by-segment interaction for pace ($F_{6,192}$=2.9, P=0.04, η^2=0.02) and a segment main effect ($F_{6,192}$=227, P<0.001, η^2=0.87). The interaction indicates that segment-by-segment changes in pace differed between lower and higher risk-perception groups, and post-hoc one-tailed independent samples *t*-tests which found a slower relative starting pace among the higher risk-perception group (Figure 4A). There was no emotional intelligence group-by-segment interaction for pace ($F_{6,192}$=0.7, P=0.61, η^2<0.01) but there was a segment main effect ($F_{6,192}$=211, P<0.001, η^2=0.87), meaning that regardless of emotional intelligence group, running speed decreased during the race (Figure 4B). An association was found between deviation of pace from average speed during the first leg and risk perception (r_{34}=-0.513, P=0.002), presented in Figure 4 C, but not with emotional intelligence (r_{34}=0.259, P=0.139), presented in Figure 4D.

Risk Perception and Emotional Intelligence Group Comparisons of Ratings of Perceived Exertion and Hazard Score

There was no risk perception group-by-segment interaction for RPE ($F_{6,156}$=1.5, P=0.19, η^2=0.03), or group main effect ($F_{1,26}$=0.5, P=0.50, η^2=0.02) but there was a segment main effect ($F_{6,156}$=17.0, P<0.001, η^2=0.38) meaning, regardless of risk perception group, RPE increased throughout the ultramarathon (Figure 5A). There was no emotional intelligence group-by-segment interaction for RPE ($F_{6,156}$=0.3, P=0.95, η^2=0.01), or emotional intelligence group main effect ($F_{1,26}$=1.3, P=0.26, η^2=0.05) but there was a segment main effect ($F_{6,156}$=16.2, P<0.001, η^2=0.38) meaning, regardless of emotional intelligence group, RPE increased throughout the ultramarathon (Figure 5B).

There was no risk perception group-by-segment interaction for hazard score ($F_{6,156}$=1.4, P=0.24, η^2<0.01), or group main effect ($F_{1,26}$=1.0, P=0.33, η^2=0.04) but there was a segment main effect ($F_{6,156}$=641.0, P<0.001, η^2=0.96) meaning, regardless of risk perception group, hazard score decreased throughout the ultramarathon (Figure 5C). There was no emotional intelligence group-by-segment interaction for RPE ($F_{6,156}$=0.6, P=0.69, η^2<0.01), or emotional intelligence group main effect ($F_{1,26}$=1.2, P=0.28, η^2=0.05) but there was a segment main effect ($F_{6,156}$=626, P<0.001, η^2=0.96) meaning, regardless of risk perception group, hazard score decreased throughout the ultramarathon (Figure 5D).

Actual vs. Predicted Pacing

Two-way within-subjects ANOVAs were used to compare check point-by-check point changes in pace (segment factor) between predicted and actual pace (prediction factor). For all subjects combined there was a prediction-by-segment interaction ($F_{6,198}$=34.1, P<0.001, η^2=0.15) and a segment main effect ($F_{6,198}$=123, P<0.001, η^2=0.70). Among lower risk-perceivers there was a prediction-by-segment interaction ($F_{6,96}$=38, P<0.001, η^2=0.20) and a segment main effect ($F_{6,96}$=87.5, P<0.001, η^2=0.72). Among higher risk-perceivers there was a prediction-by-segment interaction ($F_{6,96}$=8.9, P<0.001, η^2=0.11) and a segment main effect ($F_{6,96}$=44.3, P<0.001, η^2=0.68). Among the lower emotional intelligence group there was a prediction-by-segment interaction ($F_{6,96}$=14.4, P<0.001, η^2=0.16) and a segment main effect ($F_{6,96}$=73, P<0.001, η^2=0.67). Among the higher emotional intelligence group there was a prediction-by-segment interaction ($F_{6,96}$=23.6, P<0.001, η^2=0.15) and a segment main effect ($F_{6,96}$=50, P<0.001, η^2=0.74). Where interactions are reported this indicates segment-by-segment differences between predicted and actual pace. The exact nature of these differences were examined using post-hoc one-tailed paired-samples *t*-tests and are presented in Figures 6A-E.

Discussion

The main finding, evident in both experiments, is that perceptions of risk are significantly associated with pacing strategy. Despite the differences in exercise mode and duration of both experiments, those with a greater perception of risk were found to adopt a more conservative initial pacing strategy and therefore we accept our hypothesis. In both experiments, moderate correlations were also found between starting pace and risk-perception adding confidence to these findings, although we note in Figure 4C that there were two runners with a greater perception of risk who also adopted a relatively fast starting pace.

In both experiments, the higher risk perception groups had an initial pace that was on average 8% slower than the lower risk perception groups. It is important to note that the novice cyclists in experiment 1 started at a pace that turned out to be just below their overall average speed, whereas the experienced ultraendurance runners started at a pace around 30-40% higher than their average speed. The 5 km time-trial cyclists in experiment 1 progressively increased their speed throughout the trial whereas the ultramarathon runners progressively decreased their speed, which considering the differences in duration of these events, is consistent with previous observations (1,12). Although the interaction between experience and risk-perception was not directly measured in this study, it has been observed in other decision-making contexts (13) and therefore warrants further investigation. Although the lower risk-perception groups adopted a faster starting pace, this did not result in a better overall performance compared to the higher risk-perception groups in either the cycling time trial of experiment 1 or the ultramarathon of experiment 2. Our experiments were limited by the use of between-subjects designs that, although necessary to create different risk-perception groups, made it more difficult to determine how variations in risk-perception and associated pacing differences actually affected performance. In particular, it is not possible to conclude whether lower or higher risk-perception is most beneficial to pacing and performance although we did find that the more experienced ultramarathon runners did have greater perceptions of risk compared to the novice time-trial cyclists. This is something that does require further experimentation to establish whether altering an individual athlete's perception of risk, perhaps through some psychological intervention, results in different pacing decisions and performance.

In both experiments there was no difference between lower and higher risk-perception groups in the pattern of change in RPE or hazard score, even though there was a difference in pace. There are several explanations for this. The first and perhaps most simple explanation is that, as suggested by the RPE template model (14,17,38), pace is adjusted in order to ensure a good match between experienced and expected RPE. Thus, contrary to our previous discussion, the faster pace adopted by lower risk-perceivers was from the participants perspective no more risky than the slower relative pace adopted by the higher risk-perception group, as indicated by similar RPE responses and hazard.

An alternative explanation is that consciously experienced RPE is in fact a result of top-down processing, whereby an individual's own particular level of risk perception modifies sensations emanating from afferent feedback about the internal physiological state of the body prior to reaching conscious experience. As such, experienced perceptions of exertion already take into account risk-perception orientations such that the faster pace of the lower risk-perception group and the slower pace of the higher risk-perception group produce the same RPE. This notion of RPE being the product of top-down processes is in fact consistent with our previous work (26,24). Furthermore, it has been suggested that top-down processes provoke different perceptual outcomes because of the affective value and subjective emotional experience that are associated with the internal sensations (8,21,28).

In experiment two, there were no pacing, RPE or hazard score differences between emotional intelligence groups and therefore we reject our hypothesis. However, compared to higher risk-perceivers, the lower risk-perceivers did have a slightly lower emotional intelligence score, indicating a decreased tendency to appraise, express, regulate and use emotions. These results, taken together with the differences in pacing, perhaps suggest that lower risk-perceivers have less of a reliance on feelings than higher risk-perceivers in making pacing decisions. We stress that, because there was only a slight difference in emotional intelligence between the risk-perception groups, this conclusion is not convincingly supported yet does have intuitive appeal. In the context of the 'risk-as-feelings' model (31), it is interesting to note that affective factors naturally carry much less certainty than the kinds of informational sources associated with 'risk-as-analysis'. It is therefore surprising that higher risk-perceivers have a greater tendency to appraise, express, regulate and use emotions. A potential explanation, which needs further investigation, is that in making decisions, athletes with higher perceptions of risk draw on as many sources of information as possible including their feelings, whereas low risk-perceivers may be willing to make decisions based on fewer sources of information. In a health context, emotional intelligence has been found to mediate the relationship between individual traits and health behaviours including exercise (5,29,37). Much more work is needed to understand how emotional intelligence mediates relationships between risk-perception traits and athletic decision-making.

A negative pacing pattern was observed in the 5 km cycling time trial of experiment one whereas a positive pacing pattern was observed in the ultramarathon of experiment two. Given the huge contrast in event duration, the respective differences in pacing strategy between the two experiments are broadly what we expected to see and consistent with previous findings (1,12). What is interesting is the large discrepancies that were observed between predicted and actual pace in each experiment, especially at the beginning and the end sections. The novice cyclists actually started over 10% slower at the beginning of the time trial compared to their predictions but, in the complete opposite direction, the ultramarathon runners performed much faster at the beginning of the run than predicted. The differences between predicted and observed pacing might be a consequence of differences between novice athletes, who have much less experience upon which to base their predictions, compared to experienced athletes, whose predictions might be more accurately based on a wealth of previous experience. Consequently the novice time-trial cyclists may have set their initial pace in the belief that it was consistent with their prediction. However, as the time-trial progressed, and as they came to realise their ability, they sped up. The ultramarathon data is more difficult to account for because, as experienced runners, a good match between actual and predicted pace might be expected. The effect could have been caused by being excessively cautious with the prediction, but equally could just mean that the conscious awareness of behavioural intentions do not accurately represent the performance template, perhaps because of the way they are mentally represented is as feelings rather than as split times and average speeds.

Conclusions

Lower risk-perceivers adopt a faster start than higher risk-perceivers, although there is no difference in RPE or hazard score. Higher risk-perceivers reported a slightly greater tendency to appraise, express, regulate and use emotions, perhaps suggesting that they have a greater reliance on emotions in evaluating risks and making pacing decisions. Both studies highlight the need for more work in understanding how athletic decision-making is influenced by perceptions of risk and emotional intelligence, and whether risk-perception modification interventions or emotion regulation training can be used to improve athletic decision-making. One question of particular interest is, in seeking out and processing information to make decisions, are higher risk-perceivers more sensitive to interoceptive feedback and their feelings compared to lower risk-perceivers who might depend more on exteroceptive feedback and performance feedback? However, the most important finding from both of our experiments is that perceptions of risk are associated with different approaches to pacing the start of an event.

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Figure Legends

Figure 1. Differences in 5 km cycling pace profile between risk-perception groups (A) and risk-taking groups (B). Association between initial pace and risk-perception (C) and risk-taking (D).

Figure 2. Differences in between cycling risk-perception groups in RPE (A) and hazard score (B). Differences in between risk-taking groups in RPE (C) and hazard score (D).

Figure 3. Differences between predicted and actual pacing profile for all cycling participants pooled (A), lower risk-perceivers (B), higher risk-perceivers (C), lower risk-takers (D) and higher risk-takers (E).

Figure 4. Differences in ultramarathon pace profile between risk-perception groups (A) and emotional intelligence groups (B). Association between initial pace and risk-perception (C) and emotional intelligence (D).

Figure 5. Differences in between ultramarathon risk-perception groups in RPE (A) and hazard score (B). Differences in between emotional intelligence groups in RPE (C) and hazard score (D).

Figure 6. Differences between predicted and actual pacing profile for all ultramarathon runners pooled (A), lower risk-perceivers (B), higher risk-perceivers (C), lower risk-takers (D) and higher risk-takers (E).

Figure 1

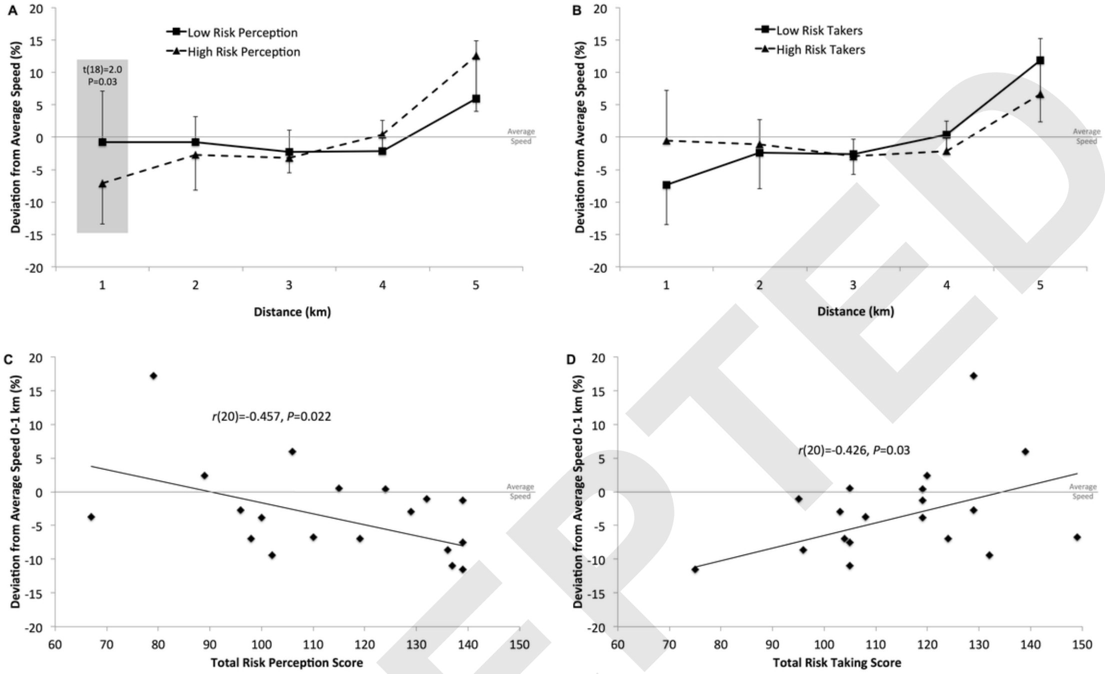

A
Low Risk Perception
High Risk Perception
t(18)=2.0
P=0.03
Deviation from Average Speed (%)
Average Speed
Distance (km)
B
Low Risk Takers
High Risk Takers
Deviation from Average Speed (%)
Average Speed
Distance (km)
C
r(20)=-0.457, P=0.022
Deviation from Average Speed 0-1 km (%)
Average Speed
Total Risk Perception Score
D
r(20)=-0.426, P=0.03
Deviation from Average Speed 0-1 km (%)
Average Speed
Total Risk Taking Score

Figure 2

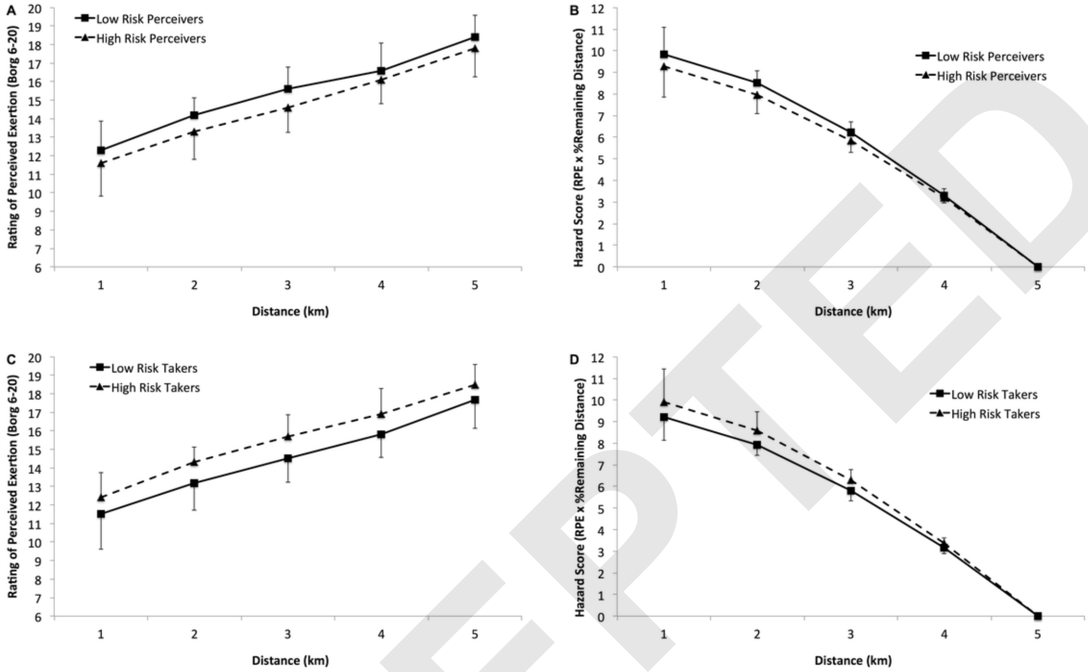
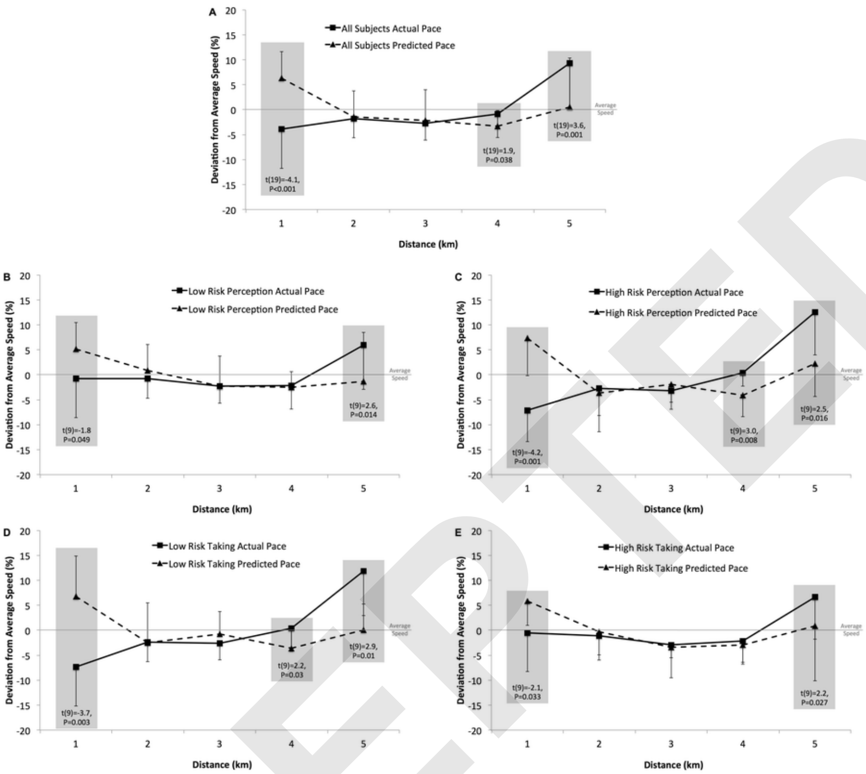

A
Low Risk Perceivers
High Risk Perceivers
Rating of Perceived Exertion (Borg 6-20)
6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
1 2 3 4 5
Distance (km)
B
Low Risk Perceivers
High Risk Perceivers
Hazard Score (RPE x %Remaining Distance)
0 1 2 3 4 5 6 7 8 9 10 11 12
1 2 3 4 5
Distance (km)
C
Low Risk Takers
High Risk Takers
Rating of Perceived Exertion (Borg 6-20)
6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
1 2 3 4 5
Distance (km)
D
Low Risk Takers
High Risk Takers
Hazard Score (RPE x %Remaining Distance)
0 1 2 3 4 5 6 7 8 9 10 11 12
1 2 3 4 5
Distance (km)

Figure 3



A
All Subjects Actual Pace
All Subjects Predicted Pace
Deviation from Average Speed (%)
Average Speed
t(19)=-4.1, P<0.001
t(19)=1.9, P=0.038
t(19)=3.6, P=0.001
Distance (km)
B
Low Risk Perception Actual Pace
Low Risk Perception Predicted Pace
t(9)=-1.8 P=0.049
t(9)=2.6, P=0.014
C
High Risk Perception Actual Pace
High Risk Perception Predicted Pace
t(9)=-4.2, P=0.001
t(9)=3.0, P=0.008
t(9)=2.5, P=0.016
D
Low Risk Taking Actual Pace
Low Risk Taking Predicted Pace
t(9)=-3.7, P=0.003
t(9)=2.2, P=0.03
t(9)=2.9, P=0.01
E
High Risk Taking Actual Pace
High Risk Taking Predicted Pace
t(9)=-2.1, P=0.033
t(9)=2.2, P=0.027
20
15
10
5
0
-5
-10
-15
-20
1
2
3
4
5

Figure 4

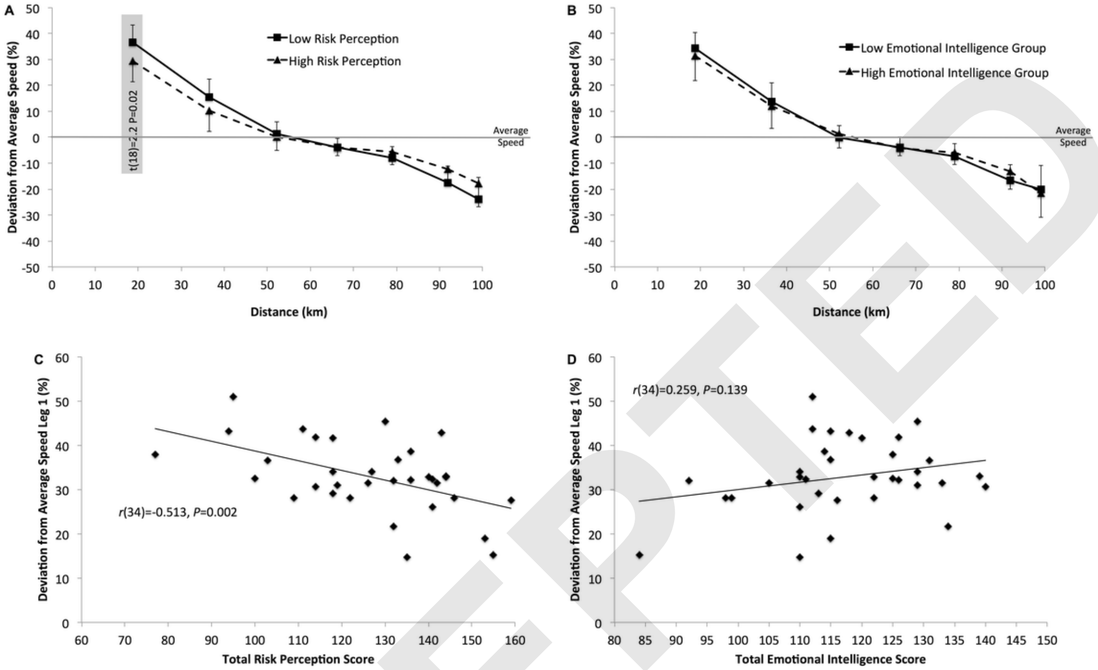

A
Deviation from Average Speed (%)
50
40
30
20
10
0
-10
-20
-30
-40
-50
t(18)=2.2 P=0.02
Low Risk Perception
High Risk Perception
Average Speed
0 10 20 30 40 50 60 70 80 90 100
Distance (km)
B
Deviation from Average Speed (%)
Low Emotional Intelligence Group
High Emotional Intelligence Group
Average Speed
0 10 20 30 40 50 60 70 80 90 100
Distance (km)
C
Deviation from Average Speed Leg 1 (%)
60
50
40
30
20
10
0
r(34)=-0.513, P=0.002
60 70 80 90 100 110 120 130 140 150 160
Total Risk Perception Score
D
Deviation from Average Speed Leg 1 (%)
r(34)=0.259, P=0.139
80 85 90 95 100 105 110 115 120 125 130 135 140 145 150
Total Emotional Intelligence Score

Figure 5

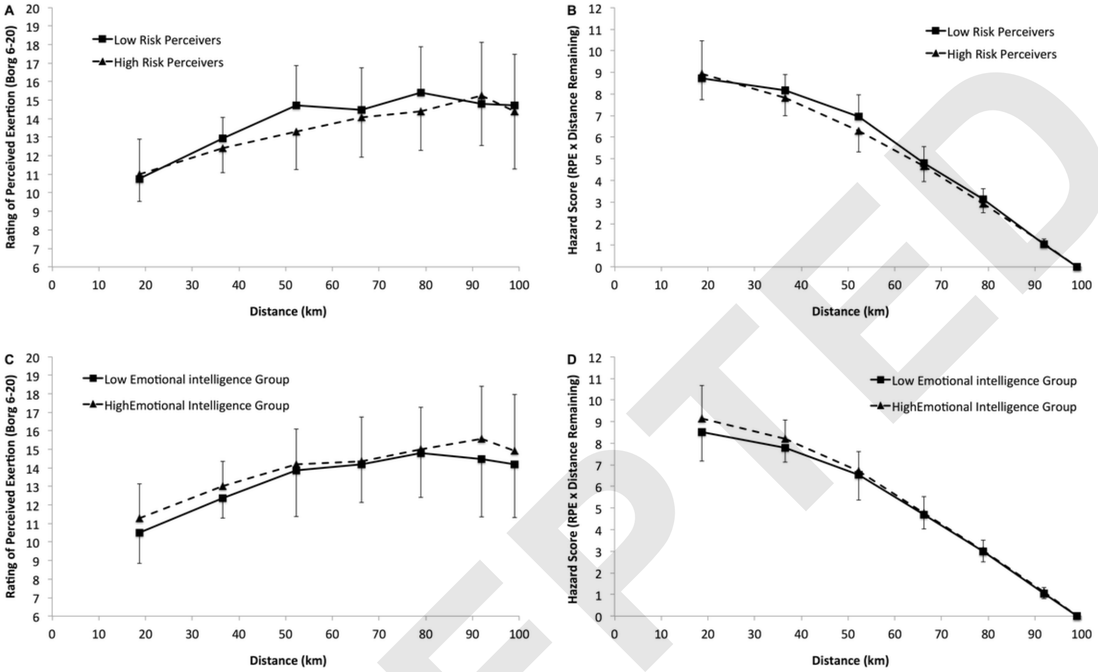
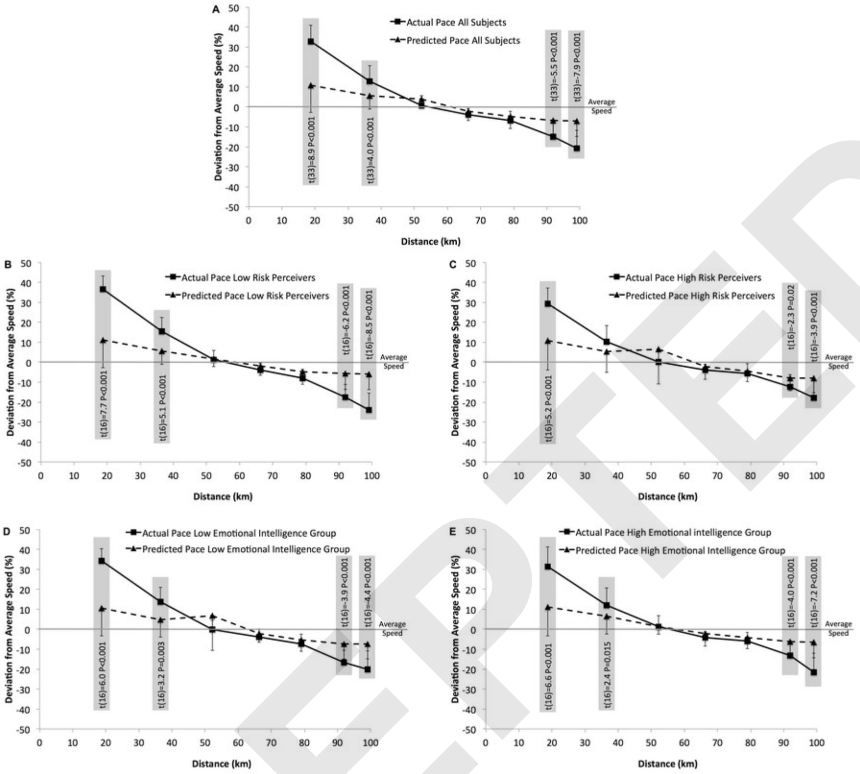

A
Rating of Perceived Exertion (Borg 6-20)
Low Risk Perceivers
High Risk Perceivers
Distance (km)
B
Hazard Score (RPE x Distance Remaining)
Low Risk Perceivers
High Risk Perceivers
Distance (km)
C
Rating of Perceived Exertion (Borg 6-20)
Low Emotional intelligence Group
HighEmotional Intelligence Group
Distance (km)
D
Hazard Score (RPE x Distance Remaining)
Low Emotional intelligence Group
HighEmotional Intelligence Group
Distance (km)
0
10
20
30
40
50
60
70
80
90
100

Figure 6


A
Actual Pace All Subjects
Predicted Pace All Subjects
t(33)=8.9 P<0.001
t(33)=4.0 P<0.001
t(33)=-5.5 P<0.001
t(33)=-7.9 P<0.001
Average Speed
Deviation from Average Speed (%)
Distance (km)
B
Actual Pace Low Risk Perceivers
Predicted Pace Low Risk Perceivers
t(16)=7.7 P<0.001
t(16)=5.1 P<0.001
t(16)=-6.2 P<0.001
t(16)=-8.5 P<0.001
Average Speed
Deviation from Average Speed (%)
Distance (km)
C
Actual Pace High Risk Perceivers
Predicted Pace High Risk Perceivers
t(16)=5.2 P<0.001
t(16)=-2.3 P=0.02
t(16)=-3.9 P<0.001
Average Speed
Deviation from Average Speed (%)
Distance (km)
D
Actual Pace Low Emotional Intelligence Group
Predicted Pace Low Emotional Intelligence Group
t(16)=6.0 P<0.001
t(16)=3.2 P=0.003
t(16)=-3.9 P<0.001
t(16)=-4.4 P<0.001
Average Speed
Deviation from Average Speed (%)
Distance (km)
E
Actual Pace High Emotional intelligence Group
Predicted Pace High Emotional Intelligence Group
t(16)=6.6 P<0.001
t(16)=2.4 P=0.015
t(16)=-4.0 P<0.001
t(16)=-7.2 P<0.001
Average Speed
Deviation from Average Speed (%)
Distance (km)
50
40
30
20
10
0
-10
-20
-30
-40
-50
0
10
20
30
40
50
60
70
80
90
100