Deviation from goal pace, body temperature and body mass loss predictors of road race performance

By: William M. Adams, Yuri Hosokawa, Luke N. Belval, Robert A. Huggins, Rebecca L. Stearns, and Douglas J. Casa

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Abstract:

Objectives: The purpose of this study was to examine the relationship between pacing, gastrointestinal temperature (T_{GI}), and percent body mass loss (%BML) on relative race performance during a warm weather 11.3 km road race. **Design:** Observational study of a sample of active runners competing in the 2014 Falmouth Road Race. **Methods:** Participants ingested a T_{GI} pill and donned a GPS enabled watch with heart rate monitoring capabilities prior to the start of the race. Percent off predicted pace ($\%_{OFF}$) was calculated for seven segments of the race. Separate linear regression analyses were used to assess the relationship between pace, T_{GI}, and %BML on relative race performance. One-way ANOVA was used to analyse post race T_{GI} (≥40 °C vs <40 °C) on pace and $\%_{OFF}$. **Results:** Larger %BML was associated with faster finish times ($R^2 = 0.19$, $p = 0.018$), faster average pace ($R^2 = 0.29$, $p = 0.012$), and a greater $\%_{OFF}$ ($R^2 = 0.15$, $p = 0.033$). $\%_{OFF}$ during the first mile (1.61 km) significantly predicted overall finish time ($R^2 = 0.64$, $p < 0.001$) while $\%_{OFF}$ during the second mile (3.22 km) (R^2 change = 0.18, $p < 0.001$) further added to the model ($R^2 = 0.82$, $p < 0.001$). Body temperature (pre race T_{GI} and post race T_{GI}) was not predictive of overall finish time ($p > 0.05$). There was a trend in a slower pace ($p = 0.055$) and greater $\%_{OFF}$ ($p = 0.056$) in runners finishing the race with a $T_{GI} > 40$ °C. **Conclusions:** Overall, finish time was influenced by greater variations in pace during the first two miles of the race. In addition, runners who minimized fluid losses and had lower T_{GI} were associated with meeting self-predicted goals.

Keywords: Hypohydration | Dehydration | Gastrointenstinal temperature | Predicted running performance

Article:

1. Introduction

There are myriad factors that can affect an individual's performance during a road race; body temperature,[1, 2] hydration status,[3, 4] and a person's ability to self-regulate their exercise intensity (pacing) have been speculated to be the largest contributors to one's performance.[5] Performance during a road race can also be influenced by the environmental conditions with increasing air temperature being identified as the most important factor adversely affecting race performance in runners.[6, 7] Proper pacing to achieve predicted or goal outcomes varies across sport and individual athletes and often relies on the athlete's experience and preparation for an event and their ability to minimize deviation from their pacing strategy.

Self-regulation of exercise intensity throughout the course of competition is essential for meeting performance goals and achieving optimal outcomes.[8] Scientific literature supports that an even pacing strategy maximises performance during endurance exercise, which conflicts with common practice where athletes often utilize a positive pacing strategy during exercise (i.e. the latter portion of the race is slower than the initial pace), especially during long duration competitions such as the marathons or Ironman distance triathlons.[5, 9] Furthermore, cognitive strategies have been shown to influence one's pacing strategy and performance; those that adjust pacing during competition based on internal cues and running ability are more apt to meet pre-competition goals.[10]

Another factor known to influence performance outcomes is body temperature. Evidence supports that as body temperature increases, there is a reduction in exercise performance that is attributed to central feedback mechanisms that maintain body temperature within a safe range.[11, 12, 13] In warm or hot conditions, when ambient temperature exceeds skin temperature, evaporation of sweat from the skin is the primary mode of dissipating heat from the body. However, this mode of heat loss is impeded when relative humidity increases, increasing the thermal strain subjected on the body.[14]

Body mass loss as a result of exercise-induced dehydration greater than 2% body mass loss has been shown to adversely affect exercise performance, especially during exercise in the heat.[3, 4] Increasing levels of dehydration reduce plasma volume, which exacerbates cardiovascular and thermoregulatory strain, especially during exercise in the heat.[4, 15, 16] Every 1% body mass loss has been shown to result in a 0.15–0.25 °C rise in body temperature[3, 4, 17] and a 3–5 beats min^{-1} rise in heart rate (HR)[4, 15] given that the intensity of exercise remains constant. Cardiovascular and thermoregulatory strain have demonstrated increased ratings of perceived exertion and results in earlier onset of fatigue, thus prompting a reduction in exercise intensity to complete the ensuing exercise session.

Although prior literature has examined the influence of pace, body temperature and body mass loss on exercise performance, there is little known about the relationship of these factors (individually, and combined) on relative (within individual) performance during a warm weather road race. Furthermore, there is little evidence describing the relationship of these factors on exercise performance during shorter duration endurance events (i.e. 10–21 km) where greater exercise intensity may be more easily attainable for the entire duration of the event. Therefore, the purpose of this study was to examine the relationship between pacing, body temperature, and percent body mass loss (%BML) on relative race performance during a warm weather 11.3 km (7mi) road race. Furthermore, we sought to determine if there were any differences between runners performing faster than their predicted finish time versus those performing slower than predicted using identified predictors of success.

2. Methods

Sixteen men (mean ± SD; age, 40 ± 12y; body mass, 76.3 ± 8.5 kg; body fat, 18.6 ± 5.6%) and sixteen women (age, 36 ± 10y; body mass, 59.8 ± 7.1 kg; body fat, 19.1 ± 5.4%) competing in the 2014 Falmouth Road Race (FRR) (ambient temperature, 25.3 ± 0.6 °C; RH, 73.9 ± 4.1%; WBGT, 23.7 °C) participated in this study, which was an observational research design. Prior to participation, runners were briefed on the benefits and risks of participating in this study. Following the briefing, runners read and signed an informed consent form that had been approved by the Institutional Review Board at the University of Connecticut and conform to the Code of Ethics of the World Medical Association (Declaration of Helsinki).

The participants were instructed to fill out a training history questionnaire that asked them to recall the road races they had competed in during the past 12 months, two-week training log (duration and volume) leading up to the 2014 FRR and to self-predict their overall pace and finish time for the race. In addition, participants were also sent an instructional video that familiarised them to the proper use of the global positioning satellite (GPS) watch and HR monitor (Run Trainer 1.0 (RT), Timex Group, Middlebury, CT) that they were going to be wearing during the race. The day before the start of the race, all participants met with the investigators to retrieve the gastrointestinal temperature (T_{GI}) pill (HQ, Inc, Palmetto, FL) that they were to ingest 6–10 h prior to the start of the race.

On the morning of the race, all participants met investigators to collect pre-race measures; participants provided a urine sample for hydration assessment using urine specific gravity (USG) (Atago Model N-1, Tokyo, Japan) and urine colour (Ucol).[18] Participants' body mass was obtained using a digital scale (Tanita Model BWB-800A, Tokyo, Japan) and body fat percentage was measured using Jackson & Pollock's 3 site skinfold method (Lange Skinfold Caliper, Cambridge, MD) at the chest, abdomen, and thigh measurements for men[19] and triceps, thigh, and suprailium for women.[20] Pre-race T_{GI} was also measured to ensure that the gastrointestinal temperature pill was still present in the body. Participants then donned the HR strap and RT, which was activated by the investigators prior to their departure to the starting line. All runners were free to consume any fluids prior to arrival and during the race as part of their normal racing hydration strategy.

Immediately upon finishing the race, all participants met the investigators at the finish line to collect the post race measures. T_{GI} was first measured to assess the body temperature immediately after the race. The investigators removed the GPS watch and HR monitor and saved the data to be uploaded at a later time. Participants then provided a urine sample to assess post-race hydration status and were weighed to assess %BML using the following equation:

$$\left(\frac{[\text{post race body mass} - \text{pre race body mass}]}{\text{pre race body mass}}\right) \times 100$$

In order to measure the participants' exercise intensity during the race, RT files were uploaded and analysed using TrainingPeaks WKO+ v3.0 software (Peaksware, LLC, Boulder, CO) to calculate average HR, average pace (min km^{-1}) as well as average HR and pace for every mile of the race. Next, for all participants, percent off goal time ($\%_{OFF}$) was calculated over total race duration using the following equation:

$$\left(\frac{[\text{actual finish time} - \text{self predicted finish time}]}{\text{predicted finish time}}\right) \times 100$$

It was assumed that the runners planned to maintain an even pace throughout the duration of the race, thus predicted pace per mile was calculated by dividing the runner's self-predicted finish time by the race distance (11.3 km). $\%_{OFF}$ was also calculated for every mile using the aforementioned equation for each respective mile. A negative value represents a faster finish time than their self-predicted finish time.

Lastly, follow-up comparisons were performed based on the relative performance of the participants. Participants were split into two separate groups, classified as high performers (HP) if they finished the race >5% better than their predicted time (n = 10), and classified as low performers (LP) if they finished the race >5% worse than their predicted finish time (n = 6). A value of 5% was chosen as the researchers determined this to be a meaningful value for this race. As an example, for a runner self-predicting a finish time of 56:00 min (4.97 min km^{-1}), a 5% deviation from their predicted finish time would be the difference of a 53:12 min to 58:48 min finish time, which would affect their overall ranking in the race in comparison to the other runners.

Statistical analyses were performed using SPSS v.21 (IBM, Armonk, New York). All data are reported as mean ± SD. Separate linear regression analyses were used to assess the relationship between $\%_{OFF}$ pace, T_{GI}, HR, and %BML on overall race performance. Where appropriate, multiple linear regression was used to examine the relationship between multiple predictors on overall race performance. A one-way ANOVA was used to analyse post race T_{GI} (≥40 °C vs <40 °C) on average pace for the entire race as a whole. In addition, one-way repeated measures ANOVA was used to analyse post race T_{GI} (≥40 °C vs <40 °C) on average pace and $\%_{OFF}$ pace during each mile mark during the race. For all significant predictors (%BML, $\%_{OFF}$ pace) of race performance, independent t-tests were used to compare mean differences between HP and LP.

3. Results

Race and physiological variables are shown in Table 1. On average, participants finished the race relatively close to their predicted finish time ($\%_{OFF}$: 0.46 ± 10.95%). Within each group (HP vs LP), there was no difference in predicted finish time, however the LP group statistically underperformed based on their predicted finish time compared to the HP group despite no differences in volume (LP, 6.4 ± 2.8 h wk^{-1}; HP, 8.6 ± 3.1 h wk^{-1}, p = 0.439) or length of training leading up to the race (LP, 6.8 ± 3.2 wks; HP, 5.6 ± 4.8 wks, p = 0.652), age, post race T_{GI}, and average HR (Table 2). Furthermore, there were no differences in volume or length of training or race experience in HP or LP when compared to those finishing the race within 5% of their self-predicted finish time ($p > 0.05$).

Table 1. Race and physiological measures.

	Males	**Females**	**Overall**
Finish time (min)	53:34 ± 8:23	57:57 ± 5:53	55:46 ± 7:28
Pace (min km^{-1})	4:44 ± 0:44	5:07 ± 0:31	4:56 ± 0:40
$\%_{OFF}$ (%)	−0.14 ± 10.69	1.06 ± 11.52	0.46 ± 10.95
%BML (%)	1.31 ± 0.56	1.07 ± 0.91	1.19 ± 0.75[a,b,c]
End race T_{GI} (°C)	39.67 ± 0.52	39.67 ± 0.82	39.67 ± 0.68

Negative value indicates faster than predicted pace; positive values indicates slower than predicted pace.
[a] Significantly predicted finish time ($r^2 = 0.19$, $p = 0.018$).
[b] Significantly predicted pace ($r^2 = 0.29$, $p = 0.012$).
[c] Significantly predicted $\%_{OFF}$ ($r^2 = 0.15$, $p = 0.033$).

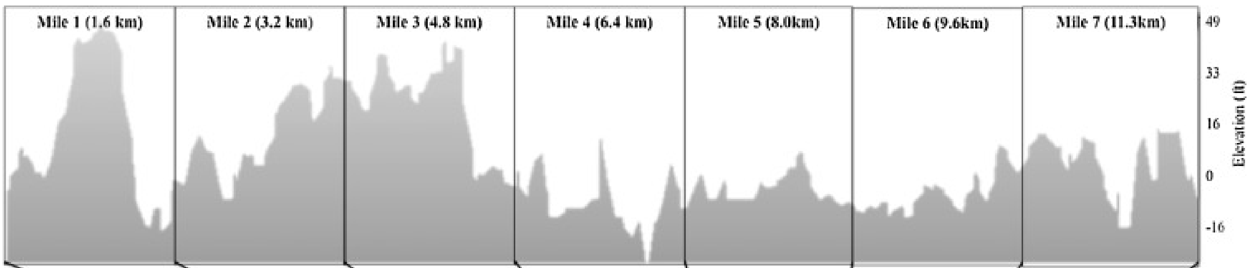
Table 2. Race performance and training.

	All participants	**HP**	**LP**	**p-Value**
Race				
Predicted finish time (min)	55.63 ± 6.15	56.45 ± 7.83	52.51 ± 5.93	p = 0.440
Actual finish time (min)	55.76 ± 7.47	**51.28 ± 8.33**	**61.89 ± 7.98**	**p = 0.012**
$\%_{OFF}$ (%)	0.46 ± 10.95	**−9.36 ± 4.04**	**18.1 ± 11.6**	**p < 0.001**
Post race T_{GI} (°C)	39.7 ± 0.7	39.62 ± 0.6	39.8 ± 0.6	p = 0.933
Average HR (beats min^{-1})	172 ± 11	169 ± 7	172 ± 15	p = 0.873
Training				
Training weeks	5 ± 5	6 ± 5	7 ± 3	p = 0.885
Training h wk^{-1}	8 ± 4	9 ± 3	6 ± 3	p = 0.504
Age (y)	38 ± 11	38 ± 11	37 ± 16	p = 0.994

Negative value indicates faster than self-predicted pace; positive value indicates slower than self-predicted pace. Values that are bolded represent significant differences ($p < 0.05$) between the HP and LP groups. $\%_{OFF}$ refers to the percent deviation of finish time from self-predicted goal finish time.

In all participants, larger %BML was associated with faster finish times ($R^2 = 0.19$, $\beta = 0.452$, $p = 0.018$), faster average pace ($R^2 = 0.29$, $\beta = 0.530$, $p = 0.012$), and a greater $\%_{OFF}$. Runners with greater %BML were more likely to finish the race faster than their pre-race goals ($R^2 = 0.15$, $\beta = 0.354$, $p = 0.033$). Examining group differences, runners classified as HP had greater losses in %BML (1.6 ± 0.55%) than those classified as LP (0.55 ± 0.95%) ($p = 0.017$).

$\%_{OFF}$ during the first 1.61 km (1 mile) significantly predicted overall finish time ($R^2 = 0.64$, $\beta = 0.803$, $p < 0.001$) while $\%_{OFF}$ at 3.22 km (2 miles) (R^2 change = 0.18, $\beta = 1.350$, $p < 0.001$) further added to the model ($R^2 = 0.82$, $p < 0.001$) (Fig. 1). Although $\%_{OFF}$ significantly predicted overall finish time, there were no differences in $\%_{OFF}$ for the first mile ($p = 0.597$) or second mile ($p = 0.293$) between HP and LP performers.



	Mile 1	Mile 2	Mile 3	Mile 4	Mile 5	Mile 6	Mile 7
% OFF Pace (%)	2.73±23.11[a]	2.19±23.27[b]	3.04±22.84	3.05±23.75	5.38±25.34	8.36±25.93	4.72±23.11
Pace ($min \cdot km^{-1}$)	4:50±0:41	4:48±0:41	4:50±0:39	4:50±0:43	4:58±0:47	5:03±0:46	4:54±0:41
HR (bpm)	157±12	170±11	172±11	173±11	175±11	175±10	177±11

[a] Significantly predicted overall race % Deviation(R^2=0.64, p<0.001); [b] Significantly predicted overall race %Deviation (R^2=0.19, p<0.001)

Figure 1. Race course topography and corresponding values related to participant performance. Segments are labelled as individual mile markers for ease of reference. $\%_{OFF}$ values labelled with [a,b] are statistically significant in relation to overall finish time.

Pre race T_{GI} and post race T_{GI} were not predictive of overall finish time among overall finishers ($R^2 = 0.001$, $p > 0.843$). There was a trend in that those finishing the race with a $T_{GI} \geq 40$ °C tended to have greater reductions in intensity (slower pace) ($p = 0.055$) and greater $\%_{OFF}$ ($p = 0.056$) throughout the duration of the race than those finishing the race with a $T_{GI} < 40$ °C. There were no differences in pre race ($p = 0.579$) and post race ($p = 0.708$) T_{GI} between HP and LP groups. Also, there was no correlation between the %BML and post race T_{GI} ($R^2 = 0.046$, $\beta = -0.214$, $p = 0.264$).

4. Discussion

The purpose of this study was to examine how body temperature, %BML, and pacing affected self-predicted performance during a summer-time warm weather road race. Our results found a negative association between those exhibiting a greater loss of body fluid during the race and race performance based on their pre-race goals. The magnitude in variation of pre-race self-predicted goal pace during the first 3.22 km (2 miles) of the race was shown to have an influence on the runner's relative performance upon completion of the race.

Our results demonstrated that the likelihood for improved race performance was attributed to the extent of body mass loss attained during competition. Prior literature has shown that dehydration greater than a level of 2% body mass loss causes performance deficits primarily due to increasing thermoregulatory and cardiovascular strain.[16, 21, 22] While our results conflict with prior research which showed that greater body water losses impaired performance,[3, 4] the magnitude of body mass loss in our study was ≤2.5% (range: −2.56% to 1.36%BML) across all participants, which may not have been a level high enough to elicit performance deficits. Furthermore, when comparing HP versus LP performers, the HP performers had a greater magnitude in mean body mass loss than LP. Some evidence suggests that increasing levels of dehydration is advantageous for performance; increasing levels of body mass loss allows individuals to exercise at the same intensity but with less body mass to move, thus potentially improving performance.[23, 24] Evidence by Zouhal et al.,[24] suggests that runners completing a marathon 4% hypohydrated perform better (faster finish times) than those completing the race less hypohydrated. However, this study failed to assess relative performance in individual runners, which prevents the ability to make a direct relationship between dehydration and performance. Although the HP finished the race with greater levels of body mass loss, the level that they attained (1.5%) was less than what would have caused noticeable performance deficits.[25, 26, 27]

The runners in this study were able to effectively meet their pre-race finish time goals ($\%_{OFF}$: 0.46 ± 10.95%). The large variation in $\%_{OFF}$ can be attributed to the few runners ($n = 4$) that varied by their self-predicted finish time by >15%. It is unknown if these runners were poor predictors of their actual finish time or if other variables were responsible for these deviations in race performance as prior race finish times, and race strategies were not assessed. When accounting for only those runners finishing the race with a $\%_{OFF} < 5\%$ ($n = 16$), we found that these runners on average deviated from their pre-race goals by −0.02 ± 2.0%, thus showing that minimizing variation in pace through the self-regulation of exercise intensity throughout the duration of the race allowed the participants to reach their pre-race goals. It may also be advantageous for these runners as most have previously run this road race; so knowing the course terrain may have assisted them in being able to accurately predict their finish time.

Evidence has shown that utilizing and maintaining an even pacing strategy optimises performance during endurance events (Pryor, Adams, Huggins, et al., Unpublished data),[9] although this strategy is not often utilized or sustainable.[5] In addition, prior research has shown that one's individual approach to a race influences race outcomes, with successful individuals being able to utilize internal cues and running ability to meet pre-determined goals.[8, 10] In the current study, the participant's predicted finish time was presumed to occur with the participant's running at a consistent pace throughout the duration of the race, however, the exact pacing strategy that each participant planned to implement or his or her running ability was not investigated.

The distance of this event (11.3 km) may have aided in the participant's ability to, on average, accurately predict their finish time over events of longer duration as prior research has shown that long duration events (i.e. marathons or triathlons) result in the poor ability of individuals to reach or predict their pre-race goal times. Longer duration events present many challenges to the individuals competing such as muscular fatigue, dehydration or other nutritional concerns,[28] whereas shorter duration events such as the Falmouth Road Race may not be long enough to result in these performance degradation factors. Our data show that on average, our participants were able to maintain a consistent pace (4:50–5:03 min km^{-1}) pace throughout the duration of the race, which may have allowed them to meet their pre-race self-predicted goal finish times.

Body temperature is well maintained within a set range to conserve homeostasis, however intense exercise in a warm environment can overwhelm this ability.[11] When the exercising individual can freely adjust the workload/intensity (i.e. running pace), the individual is likely to reduce the workload to mitigate the acute rise in body temperature to lengthen the exercise duration.[12, 25, 29] In the current study, runners who finished the race with body temperatures ≥40 °C had greater reductions in their exercise intensity, which could indicate that these runners had to reduce their workload since body temperature was reaching hyperthermia ($T_{GI} \geq 40$ °C). Furthermore, runners finishing ≥40 °C began the race running at a higher intensity than their predicted pace which may have resulted in a greater rise in body temperature, thus causing more pronounced degradations in their relative performance towards the end of the race.

This study was limited in that the runner's relative performance was related to their ability to self-predict their goal finish time without assessing their overall fitness and other physiological measures related to exercise performance. In only utilizing self-predicted finish time/pace as a measure of relative performance, it is unsure if our runners were accurate predictors of their actual abilities given that findings from other endurance events, specifically in long duration events (i.e. Ironman triathlon), competitors, on average, participants overestimated their abilities in terms of race goals.[30] Also, the individual pacing strategy for each of our runners was not assessed prior to the race; the assumption was made that all runners strived to run at a consistent intensity for the entire duration of the race given its short relative distance, which could have accounted for some of the variability in the runner's $\%_{OFF}$. Additionally, pre-race nutrition was not assessed, which may play a factor in race performance.

Future research is needed to further investigate runner's strategies for meeting pre-race goals during warm weather road races of short duration and distance. It would also be of benefit to identify other physiological factors leading to improved performance in runners exceeding their pre-race goals by a large magnitude.

5. Conclusions

Individuals participating in a summer-time warm weather road race of shorter duration (11.3 km) are able to match their predicted finish times and minimizing variation in pace may allow for improved performance relative to individual goals. Furthermore, fluid losses up to 2.5% of body mass do not impair performance during an 11.3 km warm weather road race, suggesting that this level of mild hypohydration may be acceptable for a race of this duration and intensity.

Practical applications

- During a warm weather road race such as the Falmouth Road Race, it is advantageous for competitors to minimize variation in pace throughout the race as this may positively influence resulting finish times based on previously established pre-race goals.
- Fluid losses up to 2.5% body mass do not impair relative performance during an 11.3 km warm weather road race.
- Implementing strategies to mitigate the rise in body temperature during a warm weather road race may minimize exercise hyperthermia associated declines in performance.

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