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Omission of Carbohydrate-Rich Breakfast Impairs Evening 2000-m Rowing Time Trial Performance

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Abstract

Purpose: The effect of breakfast omission on evening high-intensity exercise performance has not previously been studied. **Methods:** In a randomised and counterbalanced cross-over design, 10 competitive rowers (2 male, 8 female; mean ±SD: age 21±2 y, height 176±7 cm, weight 76±12 kg, body fat 19.7±6.8%) completed two trials (individualised carbohydrate-rich breakfast (BT; 831±67 kcal eaten before 09:00) and no-breakfast (NBT; extended overnight fast until 12:00)). Following *ad libitum* afternoon food intake, participants completed a 2000-m time-trial on a rowing ergometer between 16:30 and 18:00. Appetite and energy intake were measured throughout the day, whilst power output, time, heart rate, blood lactate, blood glucose and RPE were assessed during the time trial. **Results:** Appetite ratings were higher throughout the morning in NBT compared with BT, but there were no differences in ratings in the afternoon. Energy intake at lunch was greater NBT compared with BT (1236±594 *vs* 836±303 Kcal, $p<0.05$), which partly compensated for breakfast omission, although overall energy intake tended to be lower in NBT compared with BT (1236±594 *vs* 1589±225 kcal, $p=0.08$). The time taken to complete the 2000-m time trial was greater in NBT compared with BT (469.2±43.4 *vs* 465.7±43.3 secs; $p<0.05$). No differences in heart rate, blood glucose and blood lactate responses were apparent, but overall RPE was higher in NBT compared with BT (17.8±0.9 vs 16.7±0.7 au, $p<0.05$). **Conclusion:** These omission of a carbohydrate-rich breakfast impaired evening performance during a 2000-m rowing time trial. This finding has implications for optimising evening high intensity exercise performance.

Introduction

Prolonged endurance exercise performance is dependent on appropriate nutrition and, in particular, on adequate carbohydrate intake, in the hours prior to exercise (Burke, Hawley, Wong, & Jeukendrup, 2011). Indeed, numerous studies have demonstrated improved performance in prolonged (>60 min) endurance exercise tasks when consuming a liquid carbohydrate breakfast meal, or a mixed macronutrient but high carbohydrate breakfast meal, within 1-4 hours prior to morning exercise (Chryssanthopoulos, Williams, Nowitz, Kotsiopoulou, & Vleck, 2002; Neufer et al., 1987; Schabort, Bosch, Weltan, & Noakes, 1999; Sherman et al., 1989; Sherman, Peden, & Wright, 1991). As an example, Chryssanthopoulos et al (2002) demonstrated that high carbohydrate breakfast consumption 3 hours prior to a morning running task to exhaustion at 70% VO_2max increased time to fatigue by ~9% relative to breakfast omission. Carbohydrate intake prior to shorter duration high-intensity morning exercise also appears to enhance performance (Galloway, Lott, & Toulouse, 2014; Mears et al., 2018), although this may be due to a psychological rather than a physiological effect (Mears et al., 2018). Nevertheless, taken together, it can be inferred that a carbohydrate-rich breakfast is an important meal for optimising, whilst breakfast omission may impair, morning endurance exercise performance (Clayton & James, 2016).

More recently, it was demonstrated that the decrements in exercise performance due to breakfast omission also persist into the evening period (Clayton, Barutcu, Machin, Stensel, & James, 2015). In this study, participants either consumed or omitted a high carbohydrate breakfast and then, following an *ad libitum* lunch meal, in the evening (~9 hours post-breakfast) they performed a 60-minute cycling task, consisting of 30 minutes of matched work cycling followed by a 30 minute cycling capacity test (Clayton et al., 2015). The omission of breakfast resulted in lower energy (~500 Kcal) and carbohydrate intake (~110 grams) prior to the exercise task compared with breakfast consumption and, interestingly, work completed during the 30-minute cycling capacity test was also reduced by ~4% (Clayton et al., 2015). Due to the prolonged nature of the exercise task, this decrease in performance was ascribed (Clayton et al., 2015) to reduced skeletal muscle and liver glycogen availability as a result of the lower and/or delayed carbohydrate consumption prior to exercise with breakfast omission (Chryssanthopoulos, Williams, Nowitz, & Bogdanis, 2004; Nilsson & Hultman, 1973; Wee, Williams, Tsintzas, & Boobis, 2005).

Given that a recent survey suggested that 74% of female athletes self-report that they regularly skip breakfast (Shriver, Betts, & Wollenberg, 2013), this finding may have practical implications for optimising evening training quality and performance in evening competition (Clayton et al., 2015). However, it remains unknown whether evening performance during a high-intensity and shorter duration (~6-8 minutes) endurance task, less dependent on pre-exercise skeletal muscle and liver glycogen availability (Burke et al., 2011), would be similarly impacted by breakfast omission. Furthermore, it is not known how evening performance in an ecologically valid exercise performance task (i.e. a time trial) is impacted by breakfast omission. Thus, in the present study, we aimed to determine the effect of the omission of a carbohydrate-rich breakfast on evening 2000-m rowing performance in a cohort of trained competitive rowers. We hypothesised that carbohydrate-rich breakfast omission would impair evening 2000-m rowing performance.

Methods

Participants

Ten young and competitive University level rowers (2 male, 8 female; mean ±SD: age: 21 ± 2 y, height: 1.8±0.6 m, mass: 76±12 kg, BMI: 25±4 m/kg^2, cycling VO_2peak: 3.2±0.7 L/min, 2000-m personal best time: 465±43 secs) took part in this study and completed the full experimental procedures. All participants were recruited from Swansea University Rowing Club, were performing regular rowing based exercise training (≥4 sessions per week), were regularly competing in University and club level rowing competitions, and were self-reported regular breakfast eaters. Exclusion criteria included any existing contraindications to high-intensity exercise, as determined by the Physical Activity Readiness Questionnaire, a health history questionnaire, and/or a resting blood pressure >140/90 during screening. The requirements of the study were explained to participants both verbally, and in writing, before each participant gave their informed consent to participate. Participants were aware of the aims of the study but not the study hypothesis. The study protocol was approved by the College of Engineering Research Ethics Committee at Swansea University (approval number: 2017-039) and conducted in accordance with the Declaration of Helsinki.

Experimental Design and Pre-Experimental Procedures

A randomised and counterbalanced cross-over design was employed with two conditions: 1) individualised breakfast consumption (831±67 kcal eaten before 9am) and 2) breakfast omission (extended overnight fasting until 12pm). Prior to the main experimental trials, all participants attended the lab on two separate occasions. On the first visit, several measures of participant characterisation were collected, including height (to the nearest 0.1cm), weight (to the nearest 0.1kg), and, for characterisation of participants training status, an incremental cycling ramp test to volitional exhaustion (Lode, Excalibur Sport, Groningen, The Netherlands) to determine peak oxygen uptake capacity (VO_2peak; JAEGER Vyntus, Vyaire, IL, USA). Following a 5-minute warm-up at 50 watts, power output was increased by 25 watts per minute until volitional exhaustion (rpm <50 for 5-secs). VO_2peak was defined as the highest 30-second average VO_2 achieved during the test. The second trial involved a familiarization session where participants completed a 2000-m rowing time trial (under the same conditions as the main trial, but without any measurements taken) following habituation with the ergometer and testing procedures. All participants were also performing regular 2000-m time-trials as part of their usual training.

Main trials

The breakfast trial and the breakfast omission trial were completed in a randomised (envelope method) and counterbalanced order. All trials were separated by at least 3 and no more than 7 days. Prior to each trial, participants were asked to avoid strenuous exercise and alcohol consumption for at least 24-hours and caffeine on each of the main trial days. Participants were also instructed to avoid structured exercise, or any high-intensity physical activities, on the day prior to – and on the day of – both trial days.

During the breakfast trial, participants were provided with a standardised food package designed to meet 25% of their daily energy requirements, determined by multiplying participants resting metabolic rate (Harris and Benedict equation (Harris & Benedict, 1918)) by a physical activity level of 1.7. The macronutrient composition of the breakfast was designed to be similar to Clayton et al (2015) and consisted of 62.1±1.0% carbohydrates, 17.0±0.4% protein and 20.9±1.3% fat (Table 1). The breakfast consisted of crisped rice cereal, semi-skimmed milk, whole-meal bread, butter, strawberry jam and orange juice (Tesco, UK). Weighed food packages were provided to each participant the evening prior to the breakfast trial and participants consumed these prior to 9am (no other food except water was then permitted until 12pm). During the breakfast omission trial, participants extended their overnight fast and were permitted to drink water only (*ad libitum*) until 12pm. From 12pm onwards, participants in both trials were able to consume food and drinks *ad libitum*. Participants recorded their afternoon dietary intake in a food diary provided to them before each main trial and this was subsequently analysed for total energy, carbohydrate, fat and protein intake (Nutritics, Dublin, Ireland). Between 4:30pm and 6pm (standardised within participants), participants attended the laboratory to complete a maximal 2000-m rowing time trial. Immediately upon waking and then in hourly intervals from 9am-4pm, participants also completed 100-mm visual analogue scales for perceived hunger, fullness, prospective food consumption and desire to eat (Flint, Raben, Blundell, & Astrup, 2000) from which a composite appetite score was calculated (Desire to Eat + Hunger + (100-Fullness) + Prospective Consumption) /4 (Anderson, Catherine, Woodend, & Wolever, 2002).

2000-m Time Trial

A 2000-m time trial was chosen as a measure of performance because it is the UK governing body criterion assessment for rowing (Ingham, Pringle, Hardman, Fudge, & Richmond, 2013). Following a 5-minute warm-up (capped at a stroke rate of 20), participants completed a maximal 2000-m rowing time trial on a Concept 2 model E ergometer (Concept2, Nottingham, UK) with a drag factor of 125. Participants were instructed to complete the distance as quickly as possible and were only able to see distance remaining and their stroke rate during the test (all other variables were blinded). No form of encouragement was provided. Time, power output and heart rate were recorded every 500 metres and participants gave a rating of perceived exertion (RPE; (Borg, 1982)) score for the entire time trial on immediate completion of the test. Capillary blood samples for determination of glucose and lactate concentrations (Biosen, EKF Diagnostics, Cardiff, UK) were collected from the fingertip prior to the warm up and on immediate completion of the time trial. Data for blood analyses is presented for n=9 due to a missed blood sample during one trial.

Data analysis

Data was analysed using GraphPad Prism 7 for Mac Os X. All variables were first checked for normality using the D'Agostino & Pearson Omnibus test. The only variables to show evidence of deviation from a normal distribution were RPE, protein intake, pre-exercise glucose, and power output at two time points during the time trial. For variables where the only comparison was between the breakfast and no breakfast trials (e.g. time trial performance, nutritional variables, lactate and glucose concentrations), then paired sample t-tests were applied for normally distributed variables and Wilcoxon matched pairs analyses was applied for non-normally distributed variables. For variables with an additional factor of time (e.g. appetite ratings, power output and heart rate during the 2000-m time trial) then data were analysed using a two way (group × time) repeated measures ANOVA regardless of deviation from a normal distribution (Maxwell & Delaney, 2004). If appropriate interaction effects were observed (appetite only), pre-planned comparisons between the same time point during the breakfast and no breakfast trials were subsequently made using Fishers LSD post-hoc tests. Significance was accepted at $p<0.05$ and for consistency all data is presented as means and standard deviations unless otherwise stated.

Results

Appetite and Dietary Intake

For appetite ratings, there was a main effect of trial (p<0.01), time (p<0.001) and a trial × time interaction effect (p<0.001) (Figure 1A). There was no difference in pre-breakfast appetite ratings, but participants reported greater appetite ratings throughout the rest of the morning in the no-breakfast trial compared with the breakfast trial (p<0.001 at 09:00, 10:00 and 11:00, p<0.01 at 12:00). There were no differences in appetite ratings throughout the afternoon (i.e. post lunch).

Total energy intake in the afternoon was greater breakfast omission trial compared with the breakfast trial (p<0.05; Figure 1B), as was afternoon carbohydrate intake (p<0.05, table 1). However, there were no significant differences in afternoon protein or fat intake (table 1). Taking into account the prescribed breakfast, both carbohydrate and protein intake prior to the time trials were signficiancatly lower overall (p<0.01, table 1), and there was a tendency for lower total energy intake (p=0.08, figure 1B) with breakfast omission. There were no significant differences in overall fat intake (table 1).

Table 1. Total energy, carbohydrate, protein and fat intake at breakfast, lunch and in total during the breakfast (BT) and no breakfast (NBT) trials.

	Breakfast		**Afternoon**		**Total**	
	BT	**NBT**	**BT**	**NBT**	**BT**	**NBT**
Carbohydrate (g)	129±9	n/a	94±33	143±48*	223±36	143±48*
Fat (g)	19±3	n/a	27±13	55±43	46±12	55±43
Protein (g)	35±2	n/a	35±11	43±24	71±13	43±24*
Energy (Kcal)	831±67	n/a	758±206	1236±594*	1589±225	1236±594

*Data are presented as means and standard deviations. * denotes values significant difference between trial days (p<0.05). BT, breakfast trial. NBT, no breakfast trial.*

Time Trial Performance

There was a main effect of trial for power output over time during the 2000-m time trial (p<0.001, Figure 2A) corresponding to less time taken to complete the time trial in the breakfast trial compared with the breakfast omission trial (465.7±43.3 *vs* 469.2±43.4 secs; $p<0.05$, Figure 2B). There was no significant familiarisation effect and no significant order effect for time trial performance (familiarisation 469±45 secs, trial 1 467±43 secs, trial 2 467±44 secs, $p=0.25$ for main effect).

Heart rate increased over time during each time trial ($p<0.001$ for main effect of time), but there was no difference in this response between trials (Figure 3A). There were no differences in blood glucose concentrations prior to each time trial (4.2±0.8 and 4.3±0.5 mmol/L in the breakfast and no breakfast trial, respectively; n=9), but blood lactate concentrations were higher prior to the time trial in the breakfast trial compared to no breakfast trial (2.3±1.0 *vs* 1.5±0.3 mmol/L, respectively; n=9, $p<0.05$). There were no differences in the change in blood glucose (0.9±1.3 *vs* 1.7±1.1 mmol/L, respectively; n=9) or blood lactate (9.0±2.7 *vs* 10.4±2.7 mmol/L, respectively; n=9) in the breakfast compared with the no breakfast trials. However, participants reported higher overall ratings of perceived exertion during the time trial in the no breakfast condition compared with the breakfast condition (17.8±0.9 *vs* 16.7±0.7 arbitrary units, respectiviely; $p<0.01$, figure 3B).

Discussion

The key finding of this study was that the omission of a carbohydrate-rich breakfast impaired subsequent evening performance during a 2000-m rowing time trial. Compared with breakfast consumption, evening 2000-m rowing performance was ~3.5 seconds (~0.8%) slower following breakfast omission. This is in agreement with a recent study which observed a decrease in prolonged cycling performance in the evening following carbohydrate-rich breakfast omission in 10 recreationally active men (Clayton et al., 2015). However, these data extend the findings of Clayton et al (2015), by showing for the first time that evening performance in a short duration, high-intensity and ecologically valid performance task is also impaired in a cohort of trained competitive rowers. Several studies have reported decrements in *morning* performance during short duration high intensity exercise with breakfast omission (Galloway et al., 2014; Mears et al., 2018) but here we report for the first time that the performance decrement persists into the *evening* period. Thus, this finding is novel and also of signifance because a recent survey suggested that as many as three quarters of female athletes (our cohort was predominantly female) report regularly skipping breakfast (Shriver et al., 2013). In that context, our findings have practical implications for optimising evening training quality and for optimal preparation prior to evening performance events.

A performance decrement of ~0.8% is of practical relevance in the context of a 2000-m rowing time trial. In a comprehensive review, Smith and Hopkins (2012) reported a standard error of measurement of ~0.5% for a 2000-m time trial on a Concept 2 ergometer in trained rowers. Furthermore, they suggested that a ~0.3% improvement in rowing performance would constitute the smallest worthwhile change (Smith & Hopkins, 2012). Our cohort of competitive rowers were completing regular rowing based training and competition (>4 sessions per week) and were completing regular 2000-m time trials as part of their training. Furthermore, we observed no significant familiarisation effect and no significant order effect (trial 1 to trial 2) on rowing time trial performance. As such, we can be confident that the difference in time to complete the 2000-m time trial observed as a result of breakfast omission was greater than the day-to-day variability of the measurement and of a magnitude which would be practically meaningful for performance (Smith & Hopkins, 2012).

The potential mechanisms to explain the effect of breakfast omission on evening performance in this study are unclear. Clayton at el (2015) suggested that any performance decrement may be due to impaired liver and skeletal muscle glycogen availability due to decreased and/or delayed carbohydrate feeding in breakfast omission relative to breakfast consumption (Chryssanthopoulos et al., 2004; Nilsson & Hultman, 1973; Wee et al., 2005). Similarly we observed that total carbohydrate intake was lower (~70 grams) in breakfast omission compared with breakfast consumption, despite no significant differences in total energy intake. However, even with breakfast omission, participants in our study consumed a substantial quantity of carbohydrate approximately 3-4 hours prior to the exercise task. As such, it seems unlikely that there would have been any substantial differences in skeletal muscle or liver glycogen prior to the start of exercise in our study (Chryssanthopoulos et al., 2004; Nilsson & Hultman, 1973; Wee et al., 2005). In addition, performance during a high-intensity and shorter duration exercise task is much less likely to be impacted by small differences in skeletal muscle and liver glycogen availability (Burke et al., 2011) and we observed no evidence of hypoglyceamia prior to or following the time trial. Nevertheless, as there were small differences in total carbohydrate and total energy intake prior to the time trial, and given that we have no tissue specific data or data on substrate utilisation, we cannot rule out that the decrement in performance due to breakfast omission was the result of reduced carbohydrate and overall energy availability rather than of breakfast omission *per se*. Future studies on the effects of breakfast omission on evening exercise performance should clamp total energy and macronutrient intake prior to exercise in order to address this question.

Interestingly, a recent study suggested that the effect of breakfast on *morning* high intensity exercise performance might be explained by a placebo effect (Mears et al., 2018) and this may, in part, also explain our findings. Indeed, despite no differences in physiological markers of exertion (heart rate, blood lactate, blood glucose) our participants reported higher ratings of perceived exertion during the time trial in breakfast omission compared with the breakfast consumption. Therefore, because we did not blind participants to breakfast condition, it is possible that the perception of breakfast omission caused an expectancy of reduced performance, a higher perception of effort, and manifested in the small differences in power output observed between conditions. Future studies examining the effect of breakfast omission on evening performance should address the possibility of a placebo effect.

It is generally accepted that the omission of breakfast causes an increase in subjective appetite and as a result leads to overconsumption in subsequent meals (Pereira et al., 2011). The results of the current study were similar, as appetite was elevated with breakfast omission throughout the morning and up until the consumption of the lunch time meal (approx. 12pm). Appetite was then similar between conditions throughout the afternoon. As a result of the increased appetite, similar to previous studies (Chowdhury, Richardson, Tsintzas, Thompson, & Betts, 2015; Clayton et al., 2015; Clayton & James, 2016; Levitsky & Pacanowski, 2013), we observed greater energy intake in the afternoon in the breakfast omission condition. Despite this increase in energy intake in the afternoon, it is uncommon for this increase to be significant enough in order to fully compensate for the caloric deficit resulting from breakfast omission with studies generally reporting compensation between 0-35% following lunch (Chowdhury et al., 2015; Clayton et al., 2015; Clayton & James, 2016; Levitsky & Pacanowski, 2013). However, in the current study, we found that the energy defecit created due to breakfast omission was ~77% compensated for in the afternoon. The reasons for this discrepancy is unclear but may be related to the extended afternoon (lunch) period of measurement, the population (trained active rowers), as well the 'free-living' nature of this study compared with more typical laboratory assessments (Chowdhury et al., 2015; Clayton et al., 2015; Levitsky & Pacanowski, 2013). Indeed, in certain populations, such as overweight/obese men and women, studies have found no differences in daily energy intake following breakfast omission and breakfast consumption when under free living conditions (Chowdhury et al., 2016).

There are several limitations and avenues for future research based on the results of this study. Firstly, we did not collect information on menstrual cycle phase in our female participants and this is potential limitation. However, given that this study employed a randomised and counterbalanced design, any (possible) variance in performance due to menstrual cycle phase should not impact the validity of the inference made on the effect of breakfast omission compared with breakfast consumption. Secondly, our intervention was delivered in a 'free living' context, with participants provided with the individual prescribed breakfast to consume at home, and then recording subsequent food intake in the afternoon in a food diary. Whilst is a more ecologically valid (applied) approach and can be considered a strength of the study, there is also an opportunity for additional laboratory studies to confirm these findings, and explore different nutritional pemeatations (e.g. clamped overall energy macronutrient intake but different timing). Finally, as we took a more applied approach, we didn't include any tissue specific measures of substate availability or utilisation, so future studies aiming to provide more detailed mechanistic insight are also warrented.

In conclusion, we show here for the first time that the omission of a carbohydrate-rich breakfast impairs subsequent evening performance in a 2000-m rowing time trial. Our findings have practical implications for optimising evening exercise performance.

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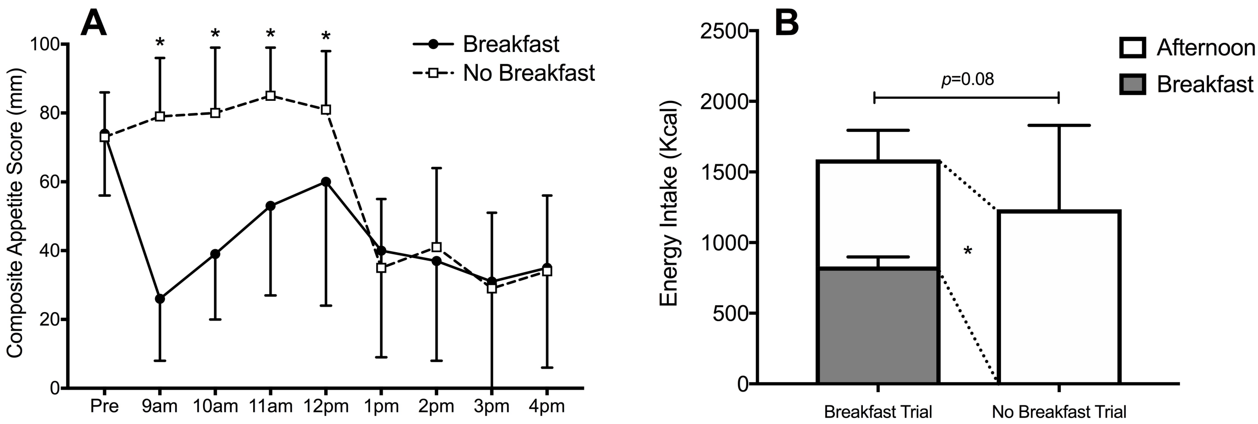

Figure 1 Appetite ratings during the day (A) and energy intake during breakfast and lunch (B) during the breakfast and no breakfast trials. All data are presented as mean ± SD. *denotes $p<0.05$ in comparison of breakfast (BT) and no breakfast (NBT).

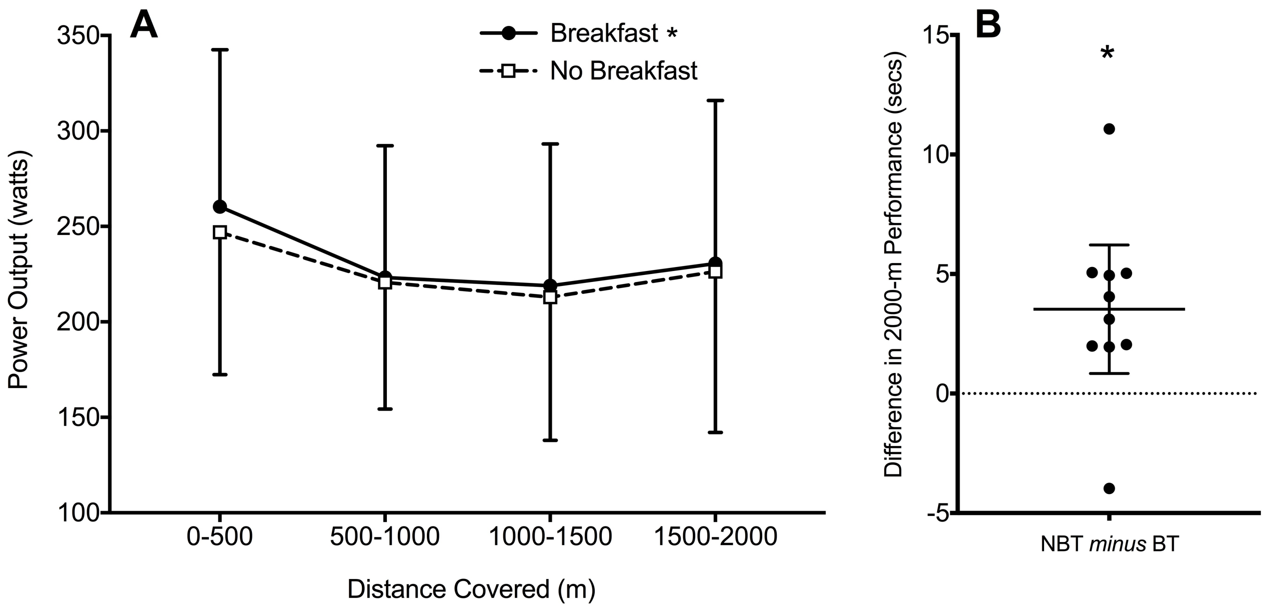

Figure 2 Power output during the 2000-m time trials (A) and the difference in time trial performance between breakfast and no breakfast trials (B). Power output data is presented as mean ± SD, whilst the difference in time trial performance is presented as the mean ± 95 CI, with black dots represententing individual participant difference scores. * denotes $p<0.05$ for comparison of breakfast (BT) and no breakfast (NBT).

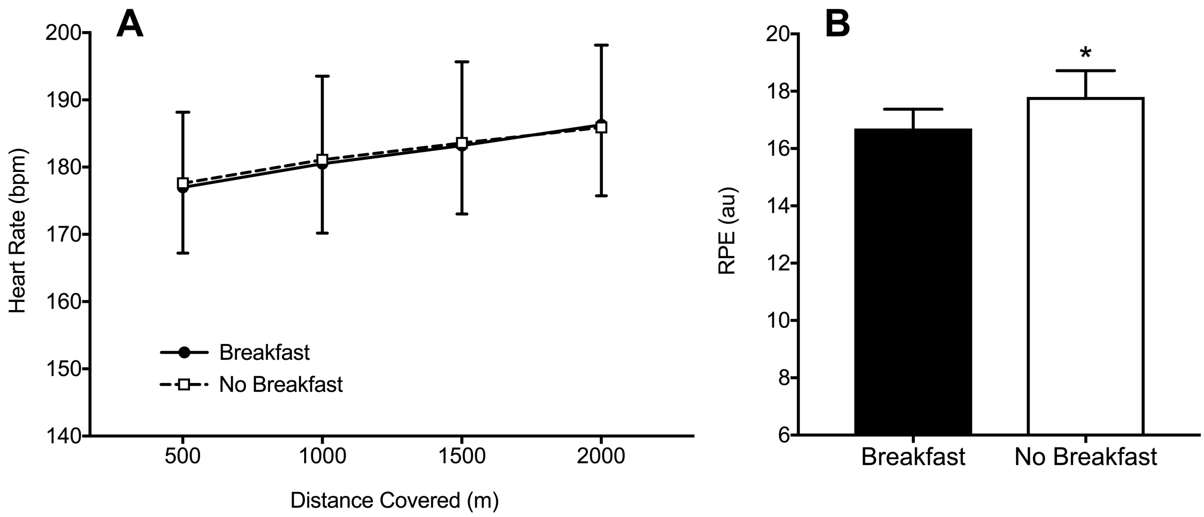

Figure 3 Heart rate responses (A) and overall RPE scores (B) during the 2000-m time trials. Data is presented as mean ± SD. * denotes $p<0.05$ for comparison of breakfast (BT) and no breakfast (NBT).