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Effects of Acute Aerobic Exercise, Dehydration and *Ad Libitum* Fluid Consumption on Mood and Choice Reaction Time in Trained Females: A Distributional Analysis

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ABSTRACT

This study investigated the effect of acute aerobic exercise, dehydration and fluid intake on choice reaction time (CRT) and the ex-Gaussian CRT distribution. On 4 separate occasions, 8 trained females (body mass [BM]: 61.8±10.7 kg; $VO_{2\ max}$: 46.3±7.5 $mL \cdot kg^{-1} \cdot min^{-1}$) lost 2.0±0.3% BM cycling at ~75% VO_{2max} (~60 min, 24.2±0.9°C) before commencing a 1 h recovery period with *ad libitum* access to one of 4 beverages: Water, Powerade® Isotonic (SD), Up&Go Energize™ (HP-MILK) and Up&Go Reduced Sugar™ (LS-MILK). Participants had an additional 15 min to consume food (e.g. muesli bars, fruit, bread and condiments) *ad libitum* at the end of the 1 h period. CRT and mood (concentration and alertness) were assessed 'Pre-Exercise', ~5 min 'Post-Exercise' and 'Post-Recovery'. Median CRT decreased Post-Exercise (401±48 ms) compared to Pre-Exercise (420±48 ms, p=0.025) and Post-Recovery values (427±49 ms, p=0.050). This improvement was localized to the μ-component of the ex-Gaussian CRT distribution (Pre-Exercise: 393±40 ms; Post-Exercise: 366±47 ms; Post-Recovery: 395±52 ms, p=0.018); the spread and skew of the distribution (i.e. σ- and τ-parameters) was unchanged across trials (p's>0.05). The effect on μ was relatively consistent across each exercise occasion (Hedges' g range: 0.32–0.63). No changes in mood were identified across time (p's>0.05). While beverage intake was similar across treatments (p=0.351), differences in total (i.e. food plus fluid) energy (p=0.014) and carbohydrate (CHO) (p<0.001) consumption were observed. Still, the type of beverage consumed did not affect mood, CRT or the ex-Gaussian CRT distribution (p's>0.05). Acute aerobic exercise provides a cognitive performance

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benefit, which appears to outweigh any adverse effects imposed by dehydration in the immediate post-exercise period in trained females.

Keywords: Cognitive function; cognitive performance; fluid intake; reaction time distribution

INTRODUCTION

Improvements in cognitive performance have been observed following acute aerobic exercise (Chang et al., 2012; Lambourne & Tomporowski, 2010; Tomporowski, 2003). These improvements, which have been observed across multiple cognitive domains, are transient, generally lasting ~15 min (Chang et al., 2012; Lambourne & Tomporowski, 2010), and are thought to occur, in part, as a result of elevated cortical concentrations of catecholamines, leading to increased physiological arousal (Chmura et al., 1998; Chmura et al., 1994). While exercise alone may enhance cognition, it is important to recognise that prolonged physical activity is often accompanied by large sweat losses (i.e. 'dehydration') (Thomas et al., 2016). When fluid losses exceed ~2.0% body mass (BM), impairments in cognitive function may occur (Masento et al., 2014). Therefore, dehydration could potentially oppose any cognitive-enhancing effects that result from physical exercise (Chang et al., 2015).

Several studies have investigated the effect of acute aerobic exercise on cognitive performance in dehydrated individuals and these have yielded inconsistent results (Grego et al., 2005; Irwin et al., 2018; Serwah & Marino, 2006; Turner et al., 2017; Wittbrodt et al., 2015; Wong et al., 2014). This inconsistency may be partly due to temporal variation in cognitive ability. Indeed, studies suggest that performance on cognitive tasks typically fluctuates from one occasion to the next. Thus, a single cognitive assessment may only capture one of many possible performance outcomes for a particular individual (Nesselroade & Salthouse, 2004; Rabbitt et al., 2001; Salinsky et al., 2001; Salthouse & Berish, 2005; Salthouse et al., 2006). To date, only one study has repeated cognitive assessments under standardized conditions to verify the magnitude and direction of exercise-induced cognitive effects in dehydrated individuals (Irwin et al., 2018). Irwin et al., (2018) observed a significant improvement in choice reaction time (CRT) in well-trained males ~15 min post-exercise, despite large fluid losses (–2.5% BM loss). The effect was replicated on 4 repeated trials that standardized exercise intensity and duration. To our knowledge, no study has measured the reproducibility of exercise-induced cognitive effects in dehydrated females. This is important, as females appear to exhibit attenuated plasma catecholamine responses to exercise compared to males (Zouhal et al., 2008), which may affect exercise-mediated cognitive performance changes (Chmura et al., 1998; Chmura et al., 1994).

The aforementioned inconsistencies (Grego et al., 2005; Irwin et al., 2018; Serwah & Marino, 2006; Turner et al., 2017; Wittbrodt et al., 2015; Wong et al., 2014) may also be due to differences in the analytical approach applied when examining performance data. For instance, reaction time, a common measure of cognitive function, is often analysed using estimates of central tendency, i.e. the mean or median response speed to a set of reaction stimuli. This can be problematic, as the "shape" of a CRT distribution can change without affecting central tendency, leading to false–negative reports (Heathcote et al., 1991). An alternative analytical approach involves fitting a distribution function to the data and using the parameters of the curve to identify regional changes in CRT performance (Ratcliff, 1979). The ex-Gaussian function, for instance, returns estimates for three parameters: (1) the mean (μ) and (2) standard deviation (SD) (σ) of the Gaussian (normal) component (i.e. the fastest reaction speeds), and (3) the mean and SD of the exponential component (τ) (i.e. the degree of positive skew) (Whelan, 2008), thereby facilitating a more comprehensive analysis of performance changes that may occur.

This study aimed to investigate the effect of acute dehydrating aerobic exercise on mood, CRT and the ex-Gaussian CRT distribution in trained females. Four standardized trials were conducted to test the reproducibility of the results. A secondary aim of this study was to determine the effect of consuming different beverages and food voluntarily (i.e. *ad libitum*) post-exercise on cognitive performance. We hypothesized that acute exercise would initially improve CRT, despite significant levels of fluid loss, and that the benefit would dissipate following a period of recovery involving consumption of food and fluid.

METHODS

The methodology of this study is provided in detail in a companion paper exploring the rehydration potential of different beverages consumed *ad libitum* with food (McCartney et al., 2019a). This manuscript will briefly summarize the methods related to the cognitive performance component of the study.

Participant Characteristics

Female cyclists/triathletes (training ≥3 h cycling·week^{-1}) aged 18–45 y were eligible to participate. A sample size calculation (G*Power Version 3.1.9, Kiel University, Germany, 2014) using a power (1-β) of 0.80, α=0.01 and effect of 0.55 (R=0.60) (Irwin et al., 2018) indicated that ~8 participants would be needed to detect a significant effect of acute exercise on CRT. To account for possible attrition, 10 volunteers were recruited. One participant withdrew due to training schedule conflicts; a second withdrew due to poor availability. Eight participants (age: 33.2±7.4 y; BM: 61.8±10.7 kg; VO_{2max}: 46.3±7.5 mL·kg^{-1}·min^{-1}; peak power output (sustainable) (PPO): 244±32 W; Mean±SD) completed all four experimental trials. The Griffith University Human Ethics Committee (GU 2017/730) approved the investigation and all procedures were undertaken in accordance with the agreement of Helsinki.

Experimental Design

Each participant attended the laboratory on 6 occasions. Initially, a medical screen and a graded cycling test to determine

VO_{2max} and PPO (see companion paper: McCartney et al. 2019a) were conducted. Participants then completed a full trial as a familiarization prior to four experimental trials (at least 5 d apart). Trial order was counterbalanced and scheduled during the follicular phase of the menstrual cycle (participants using hormonal contraceptives [*n*=3] were tested while taking the active drug). Each trial involved dehydration via exercise followed by a recovery period (1 h duration) during which *ad libitum* access to one of 4 beverages was permitted: (1) Water, (2) Powerade® Isotonic (Coca Cola Ltd.) (SD), (3) Up&Go Reduced Sugar™ (Sanitarium®, Australia) (Lower Sugar [LS]-MILK), and (4) Up&Go Energize™ (Sanitarium®, Australia) (Higher Protein [HP]-MILK). Participants had an additional 15 min to consume food *ad libitum* at the end of the 1 h period. A CRT test and subjective feelings questionnaire (SFQ) were administered 'Pre-Exercise', ~5 min 'Post-Exercise' and 'Post-Recovery'.

Pre-Trial Procedures

Prior to trials, participants were instructed to: (1) avoid alcohol (>24 h); (2) abstain from caffeine-containing products and avoid moderate-strenuous exercise (>12 h); (3) provide a record of the food/fluid they consumed (24 h); (4) consume a pre-prepared evening meal (~60 $kJ \cdot kg^{-1}$) (Campagnolo et al., 2017); and, (5) avoid food/fluid overnight (~10 h). Following the first trial, a duplicate of the food record was provided to the participant to encourage replication of dietary intake in the 24 h preceding each trial.

Experimental Procedures

On arrival to the laboratory (~7 AM), participants compliance to the pre-trial procedures was confirmed. Subsequently a sample of urine was collected and the urine specific gravity (U_{SG}; Palette Digital Refractometer, ATAGO, USA) was determined. At familiarization, one participant recorded a pre-exercise U_{SG} ≥1.024, suggesting a degree of dehydration (Armstrong et al., 2010). In response, 600 mL of water was provided to the participant who had their urine reassessed 30 min following the fluid ingestion, resulting in a U_{SG} <1.024. This beverage administration was undertaken on all subsequent trials for consistency. The remaining participants all provided initial urine samples assessed as U_{SG} <1.024 at each visit. Euhydrated participants then completed the Pre-Exercise CRT test, SFQ, and recorded a nude BM measurement.

Dehydration occurred via heat exposure (10 min; ~70°C) in a portable sauna, followed by cycling (24.2±0.9°C; 66±11% relative humidity [RH]) on an electronically-braked ergometer (Lode Excalibur Sport; Lode BV, Groningen, Netherlands). Exercise commenced at 60% PPO; individuals were permitted to adjust the intensity at 20 and 40 min (±5–10% PPO) (the minimum permitted workload = 50% PPO). Heart rate (HR) (Ambit3, Suunto®, Vantaa, Finland) was recorded every 10 min throughout exercise; respiratory gasses were also measured to allow for determination of exercise intensity and energy depended during exercise (see companion paper: McCartney, et al. 2019a).

Nude BM was measured following 60 min of exercise and when BM loss was <1.8% from baseline BM, participants continued cycling until the target BM loss was achieved. The exercise program (duration and intensity) established at the familiarization trial was replicated on the subsequent trials. Dehydrated participants completed the Post-Exercise CRT test and SFQ ~5 min after ceasing exercise. Individuals showered prior to a final nude BM measurement (i.e. ~30 min Post-Exercise). Fluid loss was estimated as the difference between the Post-Exercise BM and the Pre-Exercise BM.

Participants consumed one of 4 beverages *ad libitum* over a 1 h recovery period: (1) Water; (2) SD (Energy: 103 $kJ{\cdot}dL^{-1}$; carbohydrate [CHO]: 5.8 $g{\cdot}dL^{-1}$); (3) HP-MILK (Energy: 344 $kJ{\cdot}dL^{-1}$; CHO: 9.9 $g{\cdot}dL^{-1}$; Protein: 6.7 $g{\cdot}dL^{-1}$; Fat: 1.5 $g{\cdot}dL^{-1}$); or (4) LS-MILK (Energy: 279 $kJ{\cdot}dL^{-1}$; CHO: 8.9 $g{\cdot}dL^{-1}$; Protein: 3.4 $g{\cdot}dL^{-1}$; Fat: 1.5 $g{\cdot}dL^{-1}$). At 1 h, a variety of food items (e.g. fruit, muesli bars, bread and condiments, see McCartney, et al., 2019a) was made available which could be consumed *ad libitum* for 15 min. They then completed the Post-Recovery CRT test and SFQ. All food and fluid was weighed to the nearest 1 g to determine total beverage, energy and CHO intakes (FoodWorks ® Version 8, Xyris Software Pty Ltd, Brisbane, Australia).

Cognitive Function Test and Subjective Feelings Questionnaire

A ~2 min (40 stimuli per set) computerized 4-choice CRT test (Inquisit 4 Lab; Millisecond software, LLC, Seattle, Washington) was administered (Irwin et al., 2018). Four black boxes programed to turn red at random intervals (400–2000 ms) were displayed on a white background. Participants pressed the keyboard key corresponding to the red box as quickly as possible (each key was located directly below the corresponding stimuli). Median CRT and the percentage of correct responses to stimuli (CRT accuracy) were assessed in response to each set of stimuli. The SFQ consisted of visual analog scales (VAS) evaluating feelings of alertness and ability to concentrate. Measures were recorded on 100 mm scales, with 0 corresponding to '*not at all*' and 100 corresponding to '*extremely*' using computerized software (Adaptive VAS; Marsh-Richard et al. (2009).

Statistical Analysis

Analyses was conducted using SPSS Statistics, Version 21.0 (IBM Corp. 2012, Armonk, N.Y., USA). Initially, normality (Shapiro-Wilk test, p's>0.05) and sphericity (Mauchly's test) were examined. When assumptions of sphericity were breached, the Greenhouse-Geisser statistic was used. One-way repeated measures analysis of variance (ANOVA) was employed to determine if pre-trial conditions differed between treatments (i.e. BM and U_{SG}), fluid loss and fluid/nutrient intake. A series of 4 (Treatment) × 3 (Time) repeated-measures ANOVAs were used to examine global CRT, CRT accuracy, the ex-Gaussian parameters (μ, σ and τ) and mood ratings. Pairwise comparisons (Bonferroni) were completed where significant main effects were detected. Prior to analysing CRT data, all incorrect responses (*n*=76), correct-responses with CRT <200 ms (*n*=0) and correct responses with CRT >1000 ms (outliers) (*n*=6) were removed (Whelan, 2008). As a result, ~2% of the total data set was removed. Median CRT and response accuracy were then calculated for each set of stimuli and averaged by treatment and time point (Pre-Exercise, Post-Exercise, Post-Recovery). The Pre-Exercise CRT intra-class correlation coefficient (ICC) for was calculated via the two-way mixed average measures (absolute agreement) model; and the co-efficient of variation (CV) for Pre-Exercise CRT was calculated using the mean and SD. Effect sizes (ES) were calculated as Hedges' *g* (Hedges, 1981) using the spreadsheet by Lakens (2013). Ex-Gaussian parameters (μ, σ and τ) were obtained by employing the quartile maximum likelihood estimation procedure via QMPE 2.18 (Cousineau et al., 2004; Heathcote et al., 2002). All fits converged within 70 iterations. Statistical significance was accepted as *p*≤0.05. Data are reported as Mean±SD, unless otherwise indicated.

RESULTS

Exercise-Induced Dehydration

Pre-exercise values for BM and U_{SG} were similar across treatments (Table 1). All completed the same exercise protocol at each visit. For three individuals, the exercise duration was 70 min; while the remaining particiants cycled for 60 min. Gas exchange analysis indicated that participant's mean exercise intensity was 76±5% VO_{2max}. A 4 (Treatment) × 6 (Time) analysis of HR data identified a main effect of time, F(1.8,12.5)=16.0, *p*<0.001, respectively. While a significant main effect of treatment was also observed, F(3,12)=3.21, *p*=0.044; pairwise comparisons did not identify any differences across trials (*p*'s>0.05). BM loss did not differ significantly by treatment (Table 1) or trial order, F(3,21)=0.279, *p*=0.840.

Beverage and Nutrient Intake

Beverage intake did not differ by treatment, F(3,21)=1.15, *p*=0.351; or by trial order, F(3,21)=1.11, *p*=0.369 (Water: 852±279 g; SD: 1041±248 g; LS-MILK: 923±255

Table 1
Pre-trial conditions and exercise-induced dehydration

	Water	SD	LS-MILK	HP-MILK	F	*p*-value
Pre-exercise U_{SG}	1.012 ± 0.005	1.014 ± 0.007	1.013 ± 0.005	1.014 ± 0.008	F(3, 21) = 0.547	0.656
Pre-exercise BM (kg)	62.0 ± 10.8	61.7 ± 10.9	61.3 ± 10.5	61.6 ± 10.8	F(3, 21) = 1.69	0.201
BM loss (kg)	1.2 ± 0.2	1.2 ± 0.2	1.2 ± 0.2	1.2 ± 0.1	F(3, 21) = 0.151	0.928
BM loss (%)	2.0 ± 0.3	2.0 ± 0.4	2.0 ± 0.3	2.0 ± 0.3	F(3, 21) = 0.388	0.763

BM: Body mass; SD: Powerade® Isotonic; HP-MILK: Up&Go Energize®; LS-MILK: Up&Go Reduced Sugar ®; U_{SG}: Urine specific gravity. Values are Mean±SD.

g; HP-MILK: 991±357 g). However, differences in total (i.e. food plus fluid) energy, F(1.4,10.2)=7.47, $p=0.014$; and CHO, F(3,21)=12.0, $p<0.001$; consumption were observed. Pairwise comparisons indicated that HP-MILK increased energy intake compared to Water ($p=0.026$) (Water: 2281±1205 kJ; SD: 3458±445 kJ; LS-MILK: 3978±1233 kJ; HP-MILK: 4297±946 kJ), and that Water decreased CHO intake, compared with all other treatments (p's<0.05) (Water: 66±33 g; SD: 113±18 g; LS-MILK: 117±22 g; HP-MILK: 124±27 g).

Cognitive Performance and Mood

Global CRT Performance. Pre-Exercise CRT, F(3,21)=1.51, $p=0.242$; and response accuracy did not differ by order of trials, F(3,21)=0.179, $p=0.909$; suggesting that learning was not an influential factor on cognitive performance results observed. An ICC of 0.96 (95% CI = 0.89–0.99, $p<0.001$) was calculated for Pre-Exercise CRT across trials, indicating excellent reliability for this performance variable [31]. The degree of variability in participants' Pre-Exercise CRT across trials was calculated as a CV of 4.1%. A 4 (Treatment) × 3 (Time) analysis of median CRT identified a main effect of time, F(2,14)=8.4, $p=0.004$; with pairwise comparisons indicating a reduction in CRT Post-Exercise (401±48 ms), compared to Pre-Exercise (420±48 ms, $p=0.025$) and Post-Recovery (427±49 ms, $p=0.050$) (Figure 1). A 4 (Treatment) × 3 (Time) analysis of response accuracy failed to indicate any main or interaction effects (p's>0.05). Participants demonstrated a high degree of accuracy (99±1%) in response to stimuli at all stages of testing.

Ex-Gaussian Modelling

A 4 (Treatment) × 3 (Time) analysis of the ex-Gaussian parameter μ indicated a main effect of time, F(1.2,8.3)=8.13, $p=0.018$; with pairwise comparisons revealing a reduction in CRT Post-Exercise (366±47

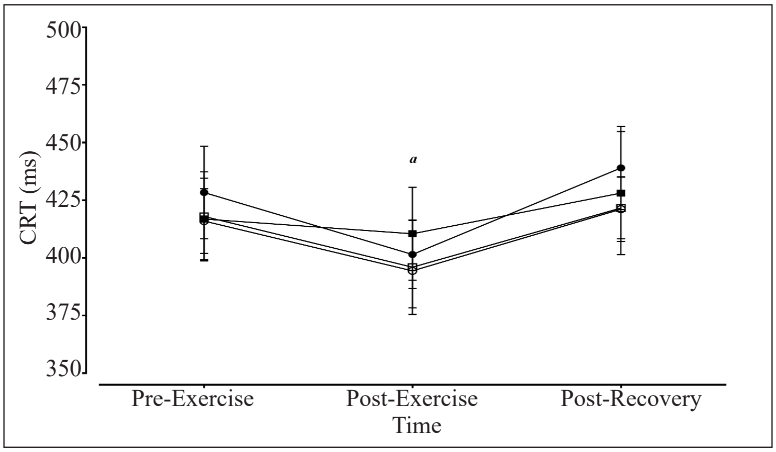


Figure 1. The effect of exercise, dehydration and beverage consumption on global median CRT. Values are Mean±SEM. Water (●); SD (○); HP-MILK (■); LS-MILK (□); *a*, Post-Exercise significantly different from Pre-Exercise and Post-Recovery (p's≤0.05).

ms), compared to Pre-Exercise (393±40, $p<0.001$) and Post-Recovery (395±52 ms, $p=0.064$) (Figure 2). The change in CRT Pre- to Post-Exercise was -29±27 ms (ES=0.57), -19±31 ms (ES=0.32), -25±25 ms (ES=0.35) and -37±20 ms (ES=0.63) on the Water, SD, LS-MILK and HP-MILK trials, respectively; indicating a relatively consistent small to moderate effect (Cohen, 1988). No other differences were observed (p’s>0.05). No main or interaction effects were observed in 4 (Treatment) × 3 (Time) analyses of σ- and τ-parameters (p’s>0.05). The whole CRT distribution is displayed in Figure 3.

Subjective Mood Ratings

No main or interaction effects were observed in 4 (Treatment) × 3 (Time) analyses of alertness and concentration (p’s>0.05) (Figure 4).

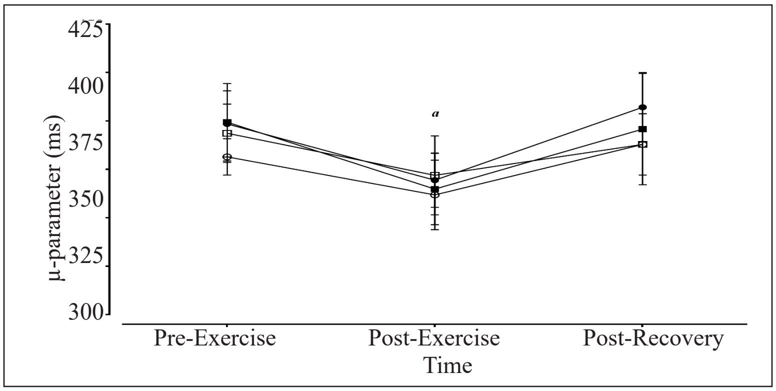


Figure 2. The effect of exercise, dehydration and beverage consumption on the μ-parameter of the Gaussian CRT distribution. Values are Mean±SEM. Water (●); SD (○); HP-MILK (■); LS-MILK (□); *a*, Post-Exercise different from Pre-Exercise ($p\leq0.05$) and Post-Recovery ($p<0.010$).

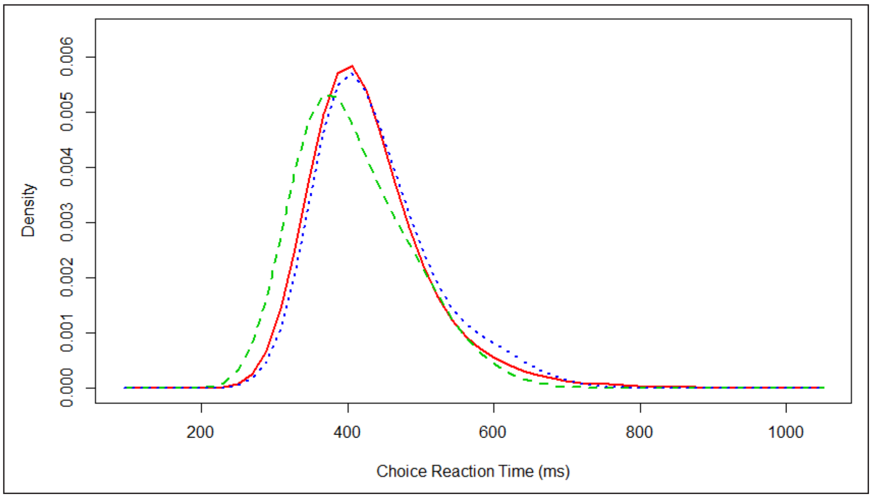
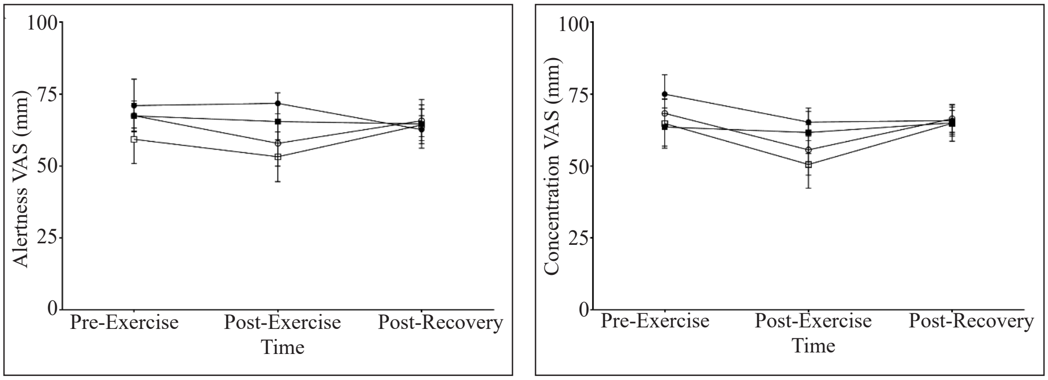


Figure 3. Kernal density plot of CRT at Pre-Exercise (solid red line), Post-Exercise (dashed green line) and Post-Recovery (dotted blue line)



(A) (B)

Figure 4. Subjective ratings of (A) alertness and (B) concentration. Values are Mean±SEM, where 0 mm represents *not at all* and 100 mm represents *extremely*. Water (●); SD (○); HP-MILK (■); LS-MILK (□). VAS: Visual Analog Scale.

DISCUSSION

This study observed a short-term performance-enhancing effect of acute aerobic exercise on CRT (response speed) in trained females, despite significant sweat loss (–2.0% BM loss). The effect was consistent across 4 separate trials that were standardized for exercise intensity and duration, energy expenditure (see companion paper: McCartney et al., 2019a), menstrual phase and level of dehydration. Ex-Gaussian analyses localized the improvement to the μ-component of the CRT distribution, suggesting that exercise improved participants' overall response speed, without affecting the variability or accuracy of responses. The cognitive benefit of exercise dissipated after a period of recovery (~1 h 45 min) with *ad libitum* consumption of different beverages and food.

In this study, CRT was significantly reduced ~5 min Post-Exercise, compared to Pre-Exercise values (-19±25 ms; ES=0.37). The percentage of correct responses to choice reaction stimuli (CRT accuracy) was unchanged throughout trials. These results are consistent with Irwin et al. (2018) who observed a temporary improvement in CRT (-20±13 ms; ES=0.55) ~15 min Post-Exercise despite significant sweat losses (–2.5% BM loss) in trained male athletes. To the authors' knowledge, only two studies (Turner et al., 2017; Wong et al., 2014) have previously investigated the effect of a single bout of aerobic exercise on cognitive function in dehydrated females; and of these, only Turner et al. (2017) assessed CRT performance. Unlike the current study, this investigation, which involved 11 females of unknown training status, failed to detect a change in CRT pre- to post-exercise with modest sweat losses (1.4% BM) (Turner et al., 2017). The contrasting result may relate to the timing of cognitive test administration, with the test battery used lasting ~45 min (i.e. concluding ~50 min post-exercise); by which time, any exercise-induced cognitive-effects may have dissipated [1-3]. Overall, findings from the current investigation and (Irwin et al. (2018)) suggest that the performance-enhancing effect of aerobic exercise on CRT in trained individuals is likely to outweigh any adverse effects imposed by dehydration (at levels ≤2.5% BM loss) during the immediate post-exercise period. However, additional research is required to determine if this beneficial effect can offset impairment caused by dehydration in a more ecologically-valid context (e.g. during skill-based sporting events).

The ex-Gaussian analyses conducted in the current study localized the cognitive improvement to the μ-component of the CRT distribution. The magnitude of the effect on μ was relatively consistent across all 4 repeated trials (ES range: 0.32–0.63), indicating a small-moderate change (Cohen, 1988). To the authors' knowledge, only one study (Davranche et al., 2006) has previously characterized the effect of acute aerobic exercise on a reaction time distribution. Unlike the current study, this investigation evaluated CRT during exercise. Also, as testing began just 3 min after exercise commenced (and lasted <20 min), participants were unlikely to be in a state of significant fluid deficit. Despite this, results from the investigation are in keeping with the present study, indicating that acute aerobic exercise significantly reduced μ (-17 ms), without affecting the σ- or τ parameters of the ex-Gaussian distribution (Davranche et al., 2006). As such, distributional analysis investigations suggest that acute aerobic exercise produces a positive effect on CRT, and that the effect is a result of a generalized improvement across the entire CRT distribution, i.e. exercise increases the participants overall response speed without affecting the spread or the skew of the CRT curve.

The performance-enhancing effect of aerobic exercise on CRT is thought to result from an increase in arousal (Chmura et al., 1998; Chmura et al., 1994). Fluid consumption has also demonstrated mood-enhancing effects in dehydrated individuals (e.g. increased vigour and decreased fatigue) (McCartney et al., 2017). In contrast, dehydration may negatively impact mood-state (Masento et al., 2014). In this study, participants' subjective ratings of alertness and concentration were unchanged across trials. Thus, neither exercise, dehydration nor fluid consumption appeared to produce a dominant effect on mood. It is possible that any adverse effects imposed by dehydration were offset by a positive effect of exercise and/or fluid intake, such that the variables assessed were unchanged (Irwin et al., 2018).

A secondary aim of this study was to determine the effect of consuming different beverages and food *ad libitum* post-exercise on cognitive function. The *ad libitum* feeding approach was employed to increase the ecological validity of the recovery environment. While the Water treatment generally decreased energy and CHO consumption compared to the other beverages (as has been reported in other studies employing similar methodology

(Campagnolo et al., 2017; McCartney et al., 2019b), these differences did not significantly alter Post-Recovery mood or cognitive function. This finding contrasts prior evidence indicating that specific macronutrients (provided as small, prescribed amounts to fasted individuals) can differentially affect mood-state and cognitive function (Jones et al., 2012). Importantly, the current feeding protocol resulted in participants consuming large total macronutrient intakes, which varied according to the available beverage. Hence, it is possible that despite consuming less CHO and energy on the Water trial, the amounts consumed where sufficient to attenuate any differences in mood and cognitive function between trials during the post-recovery window. Alternatively, a larger participant sample may be required to detect a treatment effect. The sample size calculation in this study was performed to detect a significant effect of *aerobic exercise* on CRT, as limited research has examined the dietary behavior of females in the post-exercise period. Additional studies involving larger sample sizes are required to understand how the consumption of different beverages impact cognitive performance under real-life post-exercise conditions.

CONCLUSION

This investigation employed a novel, yet comprehensive, analysis approach to investigate the effect of acute dehydrating aerobic exercise on mood and CRT in trained females. Overall, results of the current study suggest that acute aerobic exercise provides a small but significant cognitive benefit to trained females during the immediate post-exercise period, even in the presence of significant sweat losses. The exercise-mediated effect was observed as a shift in the central (mean) response times, while the spread and skewness of the response distributions remained unchanged.

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