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Research report

Voluntary drinking behaviour, fluid balance and psychological affect when ingesting water or a carbohydrate-electrolyte solution during exercise ☆

Oliver J. Peacock *, Dylan Thompson, Keith A. Stokes

Sport, Health and Exercise Science Research Group, Department for Health, University of Bath, Bath BA2 7AY, United Kingdom

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ABSTRACT

This study investigated the effects of drink composition on voluntary intake, hydration status, selected physiological responses and affective states during simulated gymnasium-based exercise. In a randomised counterbalanced design, 12 physically active adults performed three 20-min intervals of cardiovascular exercise at 75% heart rate maximum, one 20-min period of resistance exercise and 20 min of recovery with *ad libitum* access to water (W), a carbohydrate-electrolyte solution (CES) or with no access to fluids (NF). Fluid intake was greater with CES than W (1706 ± 157 vs. 1171 ± 152 mL; $P < 0.01$) and more adequate hydration was achieved in CES trials (NF vs. W vs. CES: −1668 ± 73 vs. −700 ± 99 vs. −273 ± 78 g; $P < 0.01$). Plasma glucose concentrations were highest with CES (CES vs. NF vs. W: 4.26 ± 0.12 vs. 4.06 ± 0.08 vs. 3.97 ± 0.10 mmol/L; $P < 0.05$). Pleasure ratings were better maintained with *ad libitum* intake of CES (CES vs. NF vs. W: 2.72 ± 0.23 vs. 1.09 ± 0.20 vs. 1.74 ± 0.33; $P < 0.01$). Under conditions of voluntary drinking, CES resulted in more adequate hydration and a better maintenance of affective states than W or NF during gymnasium-based exercise.

Introduction

Participation in regular physical activity and exercise is associated with numerous health benefits (Blair & Brodney, 1999; Hardman & Stensel, 2008), but of those individuals who begin an exercise programme there is an estimated 45% dropout (Marcus et al., 2006). Although numerous factors are known to determine adherence to an exercise programme (Biddle & Mutrie, 2007), one aspect of exercise with motivational relevance is the affective psychological response (e.g. any pleasant or unpleasant state) that individuals experience during exercise (Ekkekakis, Parfitt, & Petruzzello, 2011). Preliminary data provides direct evidence that a pleasurable affective response to exercise and the associated positive memory of that experience, may increase the likelihood of subsequent long-term adherence to structured exercise (Kwan & Bryan, 2010; Schneider, Dunn, & Cooper, 2009; Williams et al., 2008).

It has been proposed that a causal chain exists linking physiological strain and affective psychological responses to exercise adherence (Lind, Welch, & Ekkekakis, 2009). Hydration status has been largely ignored as a potential mediating factor in this cascade of events towards non-compliance and drop-out from exercise. This is surprising given the well-known negative consequences of hypohydration on cardiovascular and thermoregulatory function during exercise (Montain & Coyle, 1992; Sawka, Young, Francesconi, Muza, & Pandolf, 1985) and emerging evidence that a fluid deficit incurred prior to (Peacock, Stokes, & Thompson, 2011) or during exercise (Backhouse, Biddle, & Williams, 2007) corresponds with impaired affective states. Fluid intake to maintain adequate hydration can minimise these adverse effects, but acute mild and moderate hypohydration appears common in physically active adults performing free-living exercise at fitness centres with unlimited access to water (Peacock et al., 2011).

Several studies indicate that the addition of carbohydrate, sodium and flavouring to plain water stimulates greater voluntary fluid intake and more adequate hydration in exercising populations (Baker, Munce, & Kenney, 2005; Passe, Horn, Stofan, & Murray, 2004; Wilk, Rivera-Brown, & Bar-Or, 2007). Traditionally, nutritional supplementation studies have focussed on "what" the individual is feeling during exercise in terms of the strain of physical work, using subjective ratings of perceived exertion (Borg, 1973). This is conceptually distinct from measuring "how" people feel with reference to the affective response of pleasure–displeasure. The few studies that have examined the impact of nutritional manipulations on basic affect, using the Feeling Scale (Hardy & Rejeski, 1989), have reported that individuals "feel better" with ingestion of water (Backhouse et al., 2007) or a carbohydrate-electrolyte drink during exercise (Backhouse, Bishop, Biddle, & Williams, 2005; Rollo, Williams, Gant, & Nute, 2008). These states are highly relevant as they may play an important role in determining task persistence and the amount of effort that individuals commit to an exercise session (Acevedo, Gill, Goldfarb, & Boyer, 1996).

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* Corresponding author.
E-mail address: O.J.Peacock@bath.ac.uk (O.J. Peacock).

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The effectiveness of carbohydrate-electrolyte drinks in promoting fluid balance and more favourable affective responses (under conditions of voluntary fluid intake) has not been examined in recreationally active adults who participate in gymnasium-based exercise for health and fitness. This is surprising given that so many people (approximately 7 million people in the UK) are reported to exercise in this context (Fitness Industry Association., 2010) and given the potential implications for encouraging positive exercise behaviours. The purpose of this study was to examine the effects of *ad libitum* ingestion of a carbohydrate-electrolyte solution on fluid balance, physiological function and affective psychological responses to a simulated gymnasium-based exercise session in physically active adults. It was hypothesised that voluntary fluid intake would be higher, and the hypohydration level would be lower, with provision of the carbohydrate-electrolyte drink compared to water or no fluid ingestion, and that the deterioration in physiological function and psychological states would be associated with the overall level of hypohydration.

Methods

Participants

Twelve recreationally active men (age, 26 ± 5 years; body mass, 78.8 ± 9.3 kg; body fat 16.8 ± 3.2%; VO_{2max} 54.9 ± 5.9 mL kg^{-1} min^{-1}; HR_{max} 195 ± 7 b min^{-1}) provided written informed consent before participating in the study. Ethical approval was granted by the local National Health Service Research Ethics Committee. All participants were familiar with gymnasium-based exercise and reported completing 1–5 structured exercise sessions per week of at least 30 min in duration.

Preliminary measurements

Participants visited the laboratory to complete two preparatory sessions. During the first visit, each participant's one-repetition maximum for chest and leg press resistance exercises was established using a resistance training machine (Concept 2 Inc., USA). The force equivalent to 75% of one-repetition maximum was then calculated and used as the target force during the resistance exercise component of experimental trials. Thereafter, maximal oxygen uptake was determined using a continuous incremental exercise test to volitional exhaustion on a motorised treadmill. Participants ran at a constant speed against an initial gradient of 3%, which was increased by 3% every 3 min until the point of volitional fatigue. One-minute expired air samples, ratings of perceived exertion and heart rates were measured in the final minute of each stage.

During a second visit to the laboratory a tasting session was conducted to determine drink flavour preferences. Two different flavour carbohydrate-electrolyte drinks were provided to each participant in a randomised sequence. Fifty millilitres of fluid chilled to approximately 12 °C was served in 150 mL plastic disposable cups. Between samples, there was a 2–3 min interval while participants cleansed their mouth with water to clear their palate. Immediately after each drink was sampled, participants rated overall drink acceptance, using a modified version of the general labelled magnitude scale (Bartoshuk et al., 2004). The most preferred flavour CES for each individual was used during subsequent experimental trials. Thereafter, participants were fully familiarised with the experimental protocol and performed three 20-min bouts of exercise on a treadmill (Woodway, UK), cross-trainer (Technogym, UK) and cycle ergometer (SRM, Germany), respectively. During these exercise periods, the work rate equivalent to a target exercise heart rate of between 70% and 80% heart rate maximum was established for each exercise apparatus and applied for all experimental trials.

Experimental design

Participants performed three main trials in a randomized, counterbalanced order and separated by 5–10 days. Previous data describing the typical gymnasium-based exercise habits of recreationally active adults was used to inform the exercise protocol in the present study (Peacock et al., 2011), with particular reference to the mode, duration and intensity of exercise performed. In this study, cardiovascular exercise intensity was described as a percentage of heart rate maximum, and showed that adults typically self-selected an intensity of approximately 75% of heart rate maximum. Given the ecological validity of these data to adults performing gymnasium-based exercise, the work rate equivalent to this target exercise heart rate was established and set for each cardiovascular exercise mode and applied across all experimental treatments. During exercise and in recovery, participants either had *ad libitum* access to water (W), their most preferred flavour 2% carbohydrate-electrolyte solution (CES), or had no access to fluids (NF). Participants were not informed of the potential role of the different exercise conditions on psychological outcomes in an effort to reduce any expectancy effects. Moreover, each individual participant was tested alone and every effort was made to standardise any interaction between the participant and experimenter.

Pre-trial standardisation

Experimental sessions were conducted in the afternoon and at the same time of day for each participant. A 2-day dietary record was completed over the 48 h period prior to trial 1, and was then replicated before all other trials (2584 ± 615 kcal day^{-1}, 45 ± 4% carbohydrate, 37 ± 5% fat, 18 ± 5% protein, 2549 ± 599 mL day^{-1} fluid). Participants reported to the laboratory after having fasted for at least 4 h to minimise the effect of a previous meal on gastric emptying and exercise metabolism. To standardise hydration status and increase the likelihood of euhydration before each exercise trial, participants were instructed to drink 500 mL of water on waking and a further 500 mL 2 h prior to arriving at the laboratory.

Experimental protocol

Each participant arrived in the laboratory having swallowed an ingestible temperature sensor capsule 6–8 h prior to the beginning of testing for the measurement of intestinal temperature. Participants were then seated in an upright position for a period of 15 min before a pre-exercise blood sample and a 5-min expired gas sample were obtained. After participants had provided a urine sample and emptied their bladder, nude body mass was recorded. Participants were then instrumented with a chest strap and heart rate monitor, before changing into shorts, t-shirt and training shoes. The exercise protocol commenced with a 5-min warm-up on a treadmill at a work rate of between 60% and 70% heart rate maximum. Three 20-min cardiovascular exercise intervals were then performed on a treadmill, cross-trainer and a cycle ergometer at a predetermined work rate equivalent to approximately 75% of heart rate maximum, and separated by 5-min rest intervals. Participants then completed 4 sets of 10 repetitions at 75% of one repetition maximum, for chest and leg press resistance exercises and with a work to rest ratio of 60–90 s. This was followed by 20 min of seated recovery.

Throughout W and CES trials, fluids were permitted *ad libitum* during exercise, in designated rest intervals and in recovery. Heart rate and intestinal temperature were recorded continuously throughout the experimental protocol. Expired gas samples were taken for 1-min during the mid-point of cardiovascular exercise intervals, during the entire work and rest period of resistance exercise sets 3 and 7, and for a 3-min period during the mid-point of