Effect of modest hypertonic and isotonic dehydration on endurance performance in a temperate environment

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INTRODUCTION

Different methods of dehydration may explain contrasting findings concerning the effect of modest hypohydration (2-3% body mass loss) on endurance performance in a temperate environment (Armstrong *et al*, 1985; Oliver, *et al*, 2007). Commonly proposed mechanisms to explain performance decrements include increased cardiovascular and thermoregulatory strain (Cheuvront *et al*, 2003). Although limited evidence is available, psychological and perceptual factors (thermal sensation, thirst) have also been proposed as mechanisms (Sawka & Noakes, 2007). The study aim was to investigate the effect of isotonic and hypertonic dehydration, evoked by diuretics and exercise with fluid restriction, on endurance performance. Based on previous studies it was hypothesised that dehydration would reduce performance compared with the euhydrated control trial and that diuretic evoked isotonic dehydration would reduce performance more than hypertonic dehydration evoked by exercise with fluid restriction. A secondary aim was to identify mechanisms for the reduced endurance performance on dehydration trials.

MATERIALS AND METHODS

Fifteen physically active male participants (mean ± SD; age, 22.8 ± 5.4 years; height, 180.4 ± 5.0 cm; body mass, 78.9 ± 8.6 kg and VO_{2max}, 51.7 ± 6.7 ml·kg^{-1}·min^{-1}) completed three randomised 48 h trials separated by seven days. The day before the trials participants refrained from strenuous exercise and consumed their estimated fluid and food requirements [2864 ± 300 ml (35 ml·kg^{-1}·d^{-1}); 3182 ± 194 kcal·d^{-1}]. Food intake was the same on all trials but not fluid intake.

On day one of all trials at 1300 h participants completed a time to exhaustion (TTE1). After TTE1 they began one of three trials (Figure 1). On the control trial (CON) participants consumed adequate food and fluid to maintain euhydration and energy balance. On the isotonic dehydration trial (ID) participants had the same food and fluid as on CON but at 0800 h on day three they also consumed a dose of the diuretic furosemide (0.65 mg·kg^{-1}). On the hypertonic dehydration trial (HD) participants consumed the same food as on CON however they were not rehydrated following TTE1 and drinking fluids were restricted to 2ml·kg^{-1}·d^{-1} for 48 h. After 48 h the participants completed a second time to exhaustion (TTE2)

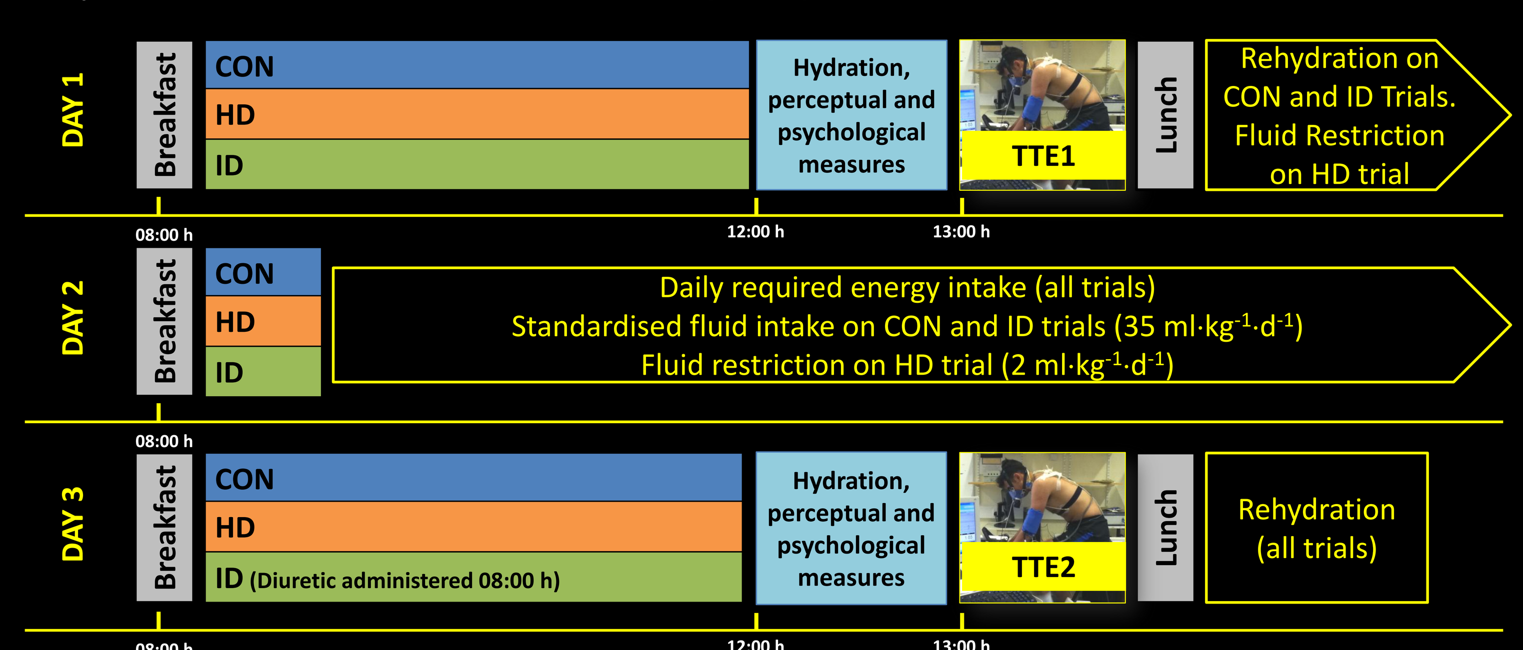

Figure 1. Schematic of the experimental protocol.

Before each TTE, body mass, plasma osmolality, urine specific gravity, thirst, thermal comfort and mood (BRUMS) were measured. During exercise, thermoregulatory (Squirrel data logger, 2020 series, Grant Instruments, Cambridge, England), cardiovascular (Physioflow, Manatec Biomedical, Paris, France) and perceptual measures were recorded every 3 min.

Data were analysed using ANOVA. Cohen's *d* effect sizes were also calculated to examine the effect of condition on TTE and on physiological and perceptual measures during TTE2 and were interpreted according to Hopkins (2004).

RESULTS

Before TTE1 nude body mass was similar on all trials and participants were euhydrated (body mass, 78.3 ± 8.4, 78.3 ± 8.3, 78.4 ± 8.7 kg; plasma osmolality, 287 ± 4, 289 ± 5, 287 ± 3 mOsm·kg^{-1}; urine specific gravity, 1.009 ± 0.004, 1.009 ± 0.004, 1.007 ± 0.003 g·ml^{-1} for CON, HD and ID respectively).

Table 1. Hydration and perceptual measures before TTE2 following the 48 h intervention.

	CON	HD	ID
Body mass change (%)	0.03 ± 0.60	-1.94 ± 0.50 *	-2.03 ± 0.3 *
Plasma volume change (%)	1.7 ± 6	-0.3 ± 6	-6.6 ± 4 ††
Plasma osmolality (mOsm·kg^{-1})	286 ± 4	296 ± 6 #	286 ± 4
Urine specific gravity (g·ml^{-1})	1.008 ± 0.004	1.028 ± 0.005 #	1.011 ± 0.004
Thirst (0-9)	3 ± 1	6 ± 1 ##	4 ± 1
Thirst - visual analogue scale (mm)	33 ± 19	69 ± 17 ##	43 ± 17
Thermal comfort (1-13)	6.5 ± 0.9	6.4 ± 1.1	6.4 ± 0.9
Fatigue	2.7 ± 2.8	5.2 ± 3.3 ##	2.9 ± 2.4
Vigour	6.9 ± 3.3	4.5 ± 3.4 ##	6.4 ± 3.0

NOTE: Values represent means ± SD, N=15.*P < 0.05 vs. CON, #P < 0.05 vs. CON and ID, ##P < 0.01 vs. CON and ID, ††P < 0.01 vs. CON and HD.

Endurance performance was reduced after modest isotonic and hypertonic dehydration in a temperate environment. Consistent with our hypothesis this reduction was greater after isotonic dehydration than hypertonic dehydration (Figure 2 and 3).

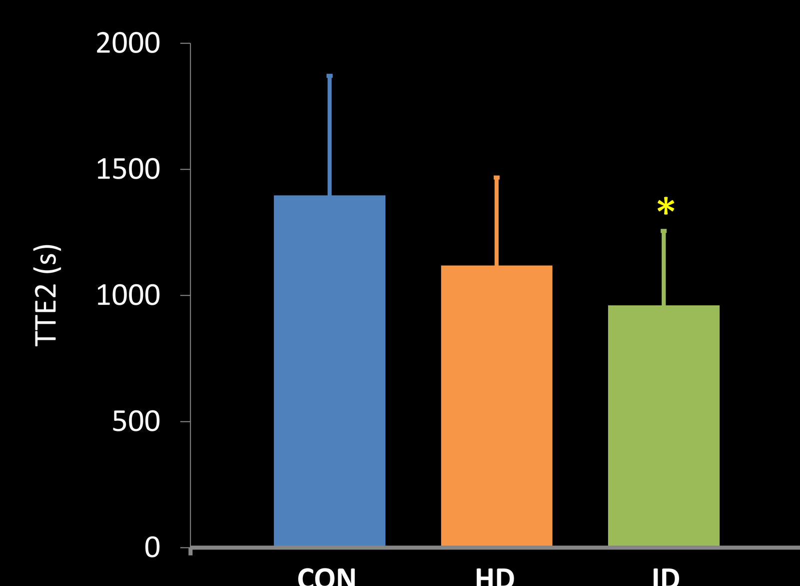

Figure 2. Times for TTE2 for control (CON), hypertonic (HD) and isotonic dehydration (ID) trials. **NOTE:** Values represent means ± SD, N = 15. *P < 0.05 vs. CON. Cohen's d effect sizes were -0.4 (small) and -0.7 (moderate) for HD vs CON and ID vs CON respectively.

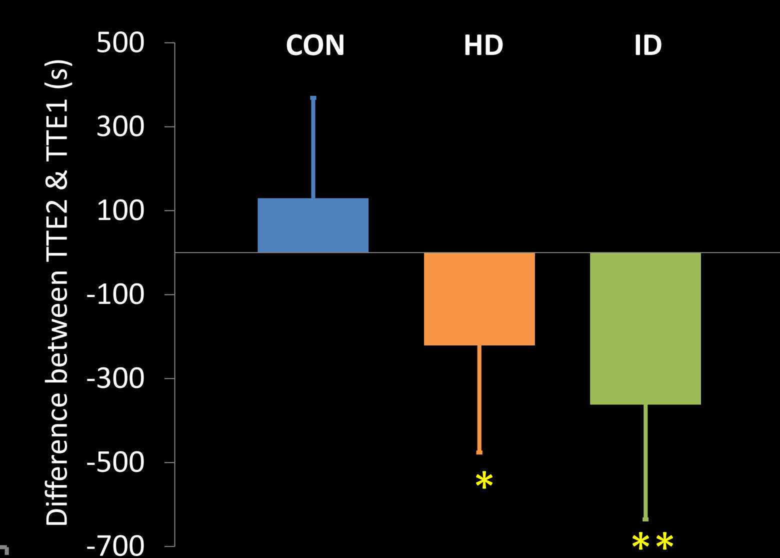

Figure 3. Difference between TTE2 and TTE1 for control (CON), hypertonic (HD) and isotonic dehydration (ID) trials. **NOTE:** Values represent means ± SD, N = 15. *P < 0.05 vs. CON, **P < 0.01 vs. CON. Cohen's d effect sizes were -1.3 (large) and -1.9 (large) for HD vs CON and ID vs CON respectively.

The results suggest that the underlying mechanisms responsible for the decline in performance are also dependent on the dehydration type. The more modest reduction in endurance performance after hypertonic dehydration is most likely caused by a decrease in mood and perceptual comfort (Table 2 and Figure 4). Indeed, cardiovascular and thermoregulatory measures, commonly proposed mechanisms by which dehydration causes reductions in performance, were unaltered in comparison with control values.

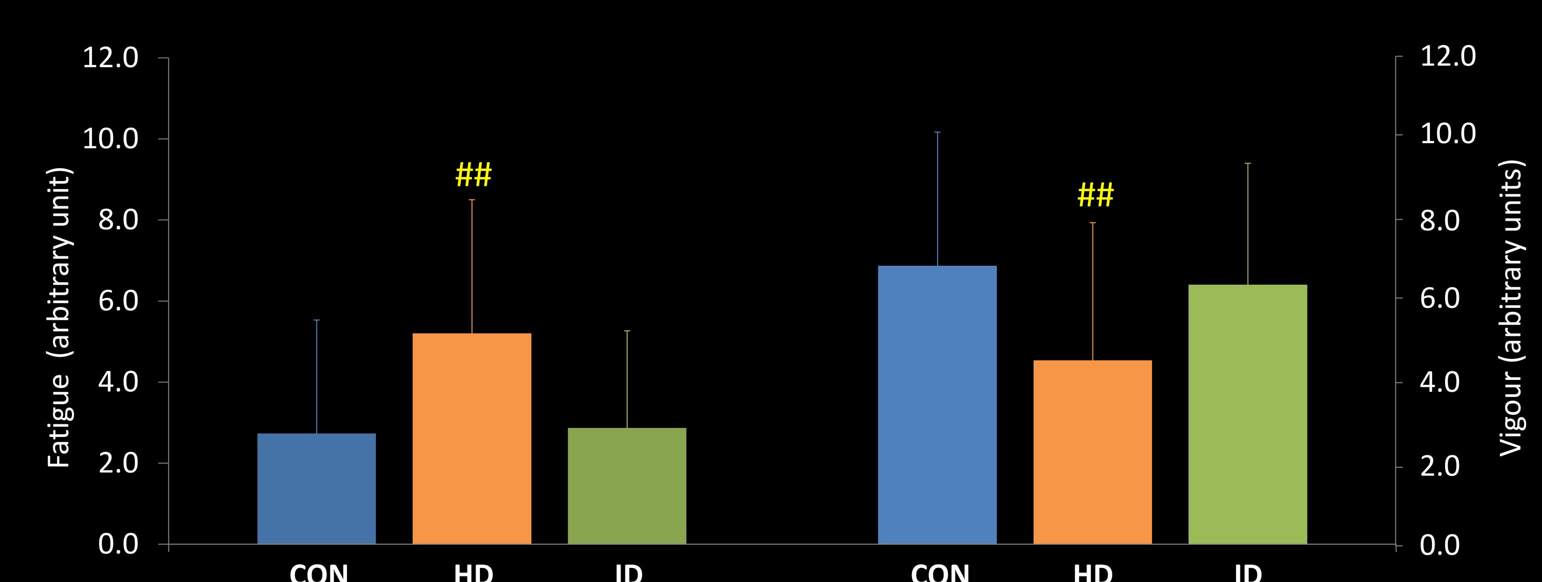

Figure 4. Fatigue and vigour (BRUMS) prior to TTE2 in control (CON), hypertonic (HD) and isotonic dehydration (ID) trials. NOTE: Values represent means ± SD, N = 15. ##P < 0.01 vs. CON and ID.

RESULTS (continued)

In contrast to hypertonic dehydration mood was unaltered after isotonic dehydration (Figure 4). The addition of cardiovascular strain to decreased perceptual comfort, also observed with hypertonic dehydration, is therefore tentatively suggested as the cause for the greater reduction in endurance performance after isotonic compared with hypertonic dehydration (Table 2). The greater cardiovascular strain can be attributed to the 7% reduction in plasma volume observed on the isotonic dehydration trial before the second time to exhaustion (Table 1)

Table 2. Mean values and standardised differences (Cohen's *d* effect size) for the first 9 minutes of TTE 2 for control (CON), hypertonic (HD) and isotonic dehydration (ID) trials.

	Mean values during TTE 2			Effect size (Cohen's *d*)	
	CON	HD	ID	HD vs CON	ID vs CON
RPE (0-10)	4.9 ± 1.4	6.1 ± 1.5 **	5.9 ± 1.7 **	0.7	0.6
Thermal comfort (1-13)	8.2 ± 0.9	8.7 ± 1.2	8.8 ± 1.1 *	0.4	0.6
Thirst (0-9)	5.4 ± 1.1	7.8 ± 1.0 ##	6.5 ± 1.3 **	2.4	1.0
Rectal temperature (°C)	37.2 ± 0.3	37.2 ± 0.3	37.3 ± 0.2	0.2	0.4
Mean skin temperature (°C)	30.8 ± 1.1	30.8 ± 1.1	30.7 ± 1.0	0.0	-0.1
Heart rate (1·min^{-1})	164 ± 10	167 ± 10	166 ± 11	0.3	0.2
Stroke volume (ml)	136 ± 12	134 ± 12	127 ± 12	-0.1	-0.6
Cardiac output (l·min^{-1})	23± 3	23 ± 3	21 ± 2	0.0	-0.4

NOTE: Values represent means ± SD, N = 15. *P < 0.05 vs. CON, **P < 0.01 vs. CON, ##P < 0.01 vs. CON and ID. Effect sizes are standardised differences in means (Cohen's *d*). Effect sizes were interpreted as ≤ 0.2 trivial, > 0.2 small, > 0.6 moderate, > 1.2 large,> 2 very large and > 4 extremely large (Hopkins, 2004). Moderate to very large effect sizes are highlighted in yellow.

CONCLUSIONS

Reductions in endurance performance and the underlying mechanisms are dependent on dehydration type and method.

Isotonic dehydration, evoked by a diuretic, causes a greater reduction in endurance performance than hypertonic dehydration, evoked by exercise with fluid restriction.

Poor mood and perceptual discomfort most likely accounts for the reduction in endurance performance with hypertonic dehydration

The addition of cardiovascular strain during exercise to perceptual discomfort most likely accounts for the greater decrease in endurance performance after isotonic compared with hypertonic dehydration.

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