ORIGINAL ARTICLE

Acute weight loss followed by an aggressive nutritional recovery strategy has little impact on on-water rowing performance

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Objectives: To assess the influence of moderate, acute weight loss on on-water rowing performance when aggressive nutritional recovery strategies were used in the two hours between weigh in and racing.
Methods: Competitive rowers (n = 17) undertook three on-water 1800 m time trials under cool conditions (mean (SD) temperature 8.4 (2.0)°C), each separated by 48 hours. No weight limit was imposed for the first time trial—that is, unrestricted body mass (UNR_1). However, one of the remaining two trials followed a 4% loss in body mass in the previous 24 hours ($WT_{-4\%}$). No weight limit was imposed for the other trial (UNR_2). Aggressive nutritional recovery strategies ($WT_{-4\%}$, 2.3 g/kg carbohydrate, 34 mg/kg Na^+, and 28.4 ml/kg fluid; UNR, ad libitum) were used in the first 90 minutes of the two hours between weigh in and performance trials.
Results: $WT_{-4\%}$ had only a small and statistically non-significant effect on the on-water time trial performance (mean 1.0 second, 95% confidence interval (CI) −0.9 to 2.8; p = 0.29) compared with UNR. This was despite a significant decrease in plasma volume at the time of weigh in for $WT_{-4\%}$ compared with UNR (−9.2%, 95% CI −12.8% to −5.6%; p<0.001).
Conclusions: Acute weight loss of up to 4% over 24 hours, when combined with aggressive nutritional recovery strategies, can be undertaken with minimal impact on on-water rowing performance, at least in cool conditions.

Whereas the performance implications of acute weight loss in athletes in weight category sports such as wrestling have received considerable attention,[1] little is known about how making weight in lightweight rowers influences on-water performance. Aside from the requirement to maintain low body fat levels to reach a predetermined body mass, athletes in wrestling and lightweight rowing share few similarities. The physiological demands of the sports differ substantially despite comparable duration of competitive efforts.[2 3] Thus existing data on wrestlers offer little insight into the performance implications of acute weight loss in lightweight rowers.

We have previously observed a small impairment in 2000 m ergometer performance in lightweight rowers who had lost 4.3% of body mass in the preceding 24 hours.[4] However, so far, we have shown the effect of controlled acute weight loss only in relation to rowing ergometer time trial performance. It has been argued that a 2000 m time trial on an ergometer may not accurately reflect the metabolic demands of on-water rowing,[5] especially in smaller boats in which it takes significantly less time to complete the effort on an ergometer than on water.[6] Furthermore, stationary rowing ergometry does not require the same degree of skill as on-water rowing.[7] Thus the performance implications of acute weight loss on the ergometer may not be wholly representative of those experienced on water.

The primary aim of this study was to examine the effect of acute weight loss on on-water performance in lightweight rowers when aggressive nutritional recovery strategies are used in the two hours between weigh in and competition. We hypothesised that, despite the use of aggressive recovery strategies in the two hour recovery period, acute weight loss would impair on-water rowing performance.

METHODS

Subjects

Seventeen nationally competitive male (n = 8) and female (n = 9) lightweight rowers participated in this study, which formed part of a larger investigation.[4] After being informed of the nature and possible risks of the investigation, each athlete provided written informed consent. This study was approved by the Human Research Ethics Committee of the Australian Institute of Sport.

Overview

All athletes participated in a regatta simulation on the rowing ergometer for the two weeks before this investigation.[4] Immediately preceding this, volunteers followed a standardised training programme for four weeks. Female volunteers were prescribed a monophasic oral contraceptive (30 µg ethinyl oestradiol, 150 mg norethisterone; Microgynon 30) throughout the six weeks of preparation and during this study to ensure maintenance of oestrogen and progesterone concentrations. Athletes kept a daily log of duration, mode, intensity, and frequency of training beginning six weeks before and continuing throughout the experimental period. The diary was used to assess compliance with the training programme and monitor acute weight loss strategies.

Overnight fasted, bladder voided, nude body mass was measured soon after waking on each day of the investigation on a calibrated digital scale with a resolution of ±0.02 kg (A and D Co, Tokyo, Japan). Before the weigh in each morning, a midstream urine sample (about 20 ml) was collected during bladder evacuation and analysed in duplicate for osmolality by the freezing point depression method using an Osmomat 030-D cryogenic osmometer (Gonotech, Berlin, Germany).

Subjects performed three maximal 1800 m on-water time trials (course length, Canberra, Australia), each separated by 48 hours. No limit was imposed on body mass for the first time trial (UNR_1). One of the remaining two time trials was undertaken after 4% body mass loss in the preceding 24 hours ($WT_{-4\%}$). The other was unrestricted (UNR_2)—that is, apart from the order of the trials, UNR_1 and UNR_2 were the same. Athletes were ranked according to sex and previous ergometer performances during the standardised training phase. The ranking was used to assign athletes to two fitness and sex matched groups which were counterbalanced for the order of the second and third time trials—that is, UNR_2 and $WT_{-4\%}$.

Food and training diaries were used to standardise dietary intake and training in the 24 hours before each 1800 m time trial. Whatever was consumed in the 24 hours before UNR_1 was also consumed before UNR_2. All athletes were provided with advice on maintaining dietary logs and periodically met a qualified dietician to ensure compliance with recommendations. Food diaries were evaluated and analysed using the Foodworks dietary analysis program (version 3.02; Xyris Software, Brisbane, Australia).

Training in the 24 hours preceding each time trial simulated that habitually undertaken during a regatta. However, athletes were permitted to undertake additional exercise before $WT_{-4\%}$ to assist in achieving their specified body mass limits. No restrictions were imposed on techniques used to induce weight loss. All athletes had personal experience in the use of acute weight loss strategies before competition.

Experimental protocol

Athletes presented at the regatta course 140 minutes before they were scheduled to start each 1800 m time trial (fig 1). After they had sat quietly on a rowing ergometer for 15 minutes, 6 ml of blood was sampled by venepuncture without stasis from a superficial forearm vein using standard phlebotomy procedures. A total of 4 ml of blood was placed in a serum separation tube and centrifuged at 4000 rpm for five minutes. The resultant serum was analysed in duplicate for osmolality. Remaining serum from female athletes was stored at −80°C and later analysed for progesterone and oestrogen using chemiluminescence technology (Vitros Eci; Ortho-Clinical Diagnostics, Raritan, New Jersey, USA). A further 2 ml aliquot of blood was mixed in a tube containing ethylene diaminetetra-acetate (potassium salt). Packed cell volume and haemoglobin concentration were measured in triplicate using an automated flow cytometry haematology analyser (ADVIA 120; Bayer Diagnostics, Tarrytown, New York, USA); the mean result was used in analyses. Relative changes in plasma volume were calculated by the method of Dill and Costill.[8] Changes in plasma volume were calculated and expressed relative to packed cell volume and haemoglobin concentration measured while subjects were in a euhydrated state, before UNR_1.

Immediately after blood sampling, bladder voided body mass was recorded on a calibrated digital scale with a resolution of ±0.02 kg. During the next 80–90 minutes, subjects consumed a standard meal (toasted bread, Vegemite, Power Bar, Carboshotz, Gastrolyte, Gatorade, water). Food and fluid intake was prescribed for $WT_{-4\%}$ (2.3 g/kg carbohydrate, 34 mg/kg Na^+, and 28.4 ml/kg fluid); fluid

Table 1 Physiological and anthropometric characteristics of participants

Variable	Male (n = 8)	Female (n = 9)
Age (years)	22.3 (3.9)	22.6 (4.1)
Height (cm)	183.2 (1.8)	171.7 (5.0)
Mass (kg)	74.2 (1.3)	63.2 (2.6)
$\dot{V}O_2$PEAK		
litres/min	4.7 (0.2)	3.5 (0.2)
ml/kg/min	64.5 (2.5)	55.0 (3.1)

Values are mean (SD).
$\dot{V}O_2$PEAK, Peak oxygen uptake.

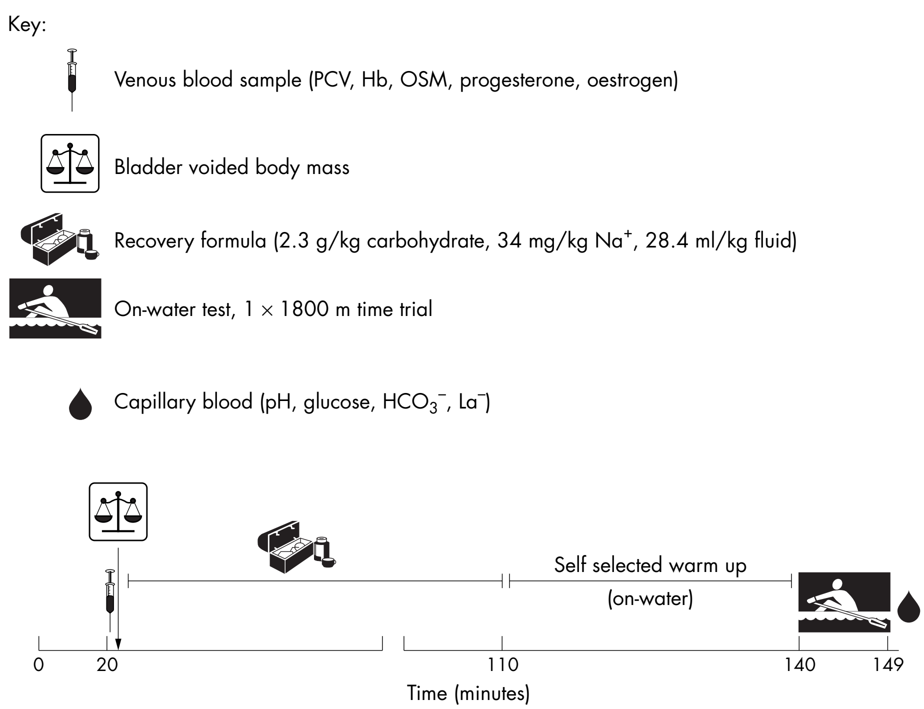

Figure 1 An overview of testing commitments undertaken during each 1800 m time trial. PCV, Packed cell volume; Hb, haemoglobin; OSM, osmolality; HCO_3^-, bicarbonate; La^-, lactate.

intake was ad libitum in unrestricted trials, although equivalent fluid and food choices were made available.

Two hours after weigh in and after a self selected warm up that was individually matched for all three trials, athletes began their time trials. Performance times were recorded using synchronised watches (Seiko, Tokyo, Japan) in split mode. Split times and stroke rates were recorded after the completion of 300, 800, and 1300 m of the 1800 m course. Environmental conditions were measured (Kestrel 4000; Nielsen-Kellerman Co, Chester, Pennsylvania, USA) immediately after the recording of split times. About two minutes after completion of each time trial, an arterialised capillary earlobe sample was collected and immediately placed on ice for later analysis of pH plus glucose, bicarbonate, and lactate concentrations (ABL 725; Radiometer, Copenhagen, Denmark). The analyser was calibrated daily in accordance with the manufacturer's specifications.

Statistical analysis

Changes in the mean of variables from the three on-water time trials were compared using a linear mixed effects model, with time trial duration as the response variable, sex, body mass (UNR or $WT_{-4\%}$), and trial number (trial 1, trial 2, and trial 3) as fixed effects, and subject as a random effect. Biochemical variables and plasma volume were compared using a mixed model analysis, with sex and body mass as fixed effects and subject as a random effect. All subsequent results are reported as mean of the difference between $WT_{-4\%}$ and UNR (collapsed over UNR_1 and UNR_2) values, together with 95% confidence intervals (CI) for the difference and a p value for testing mean difference = 0. The mixed method analysis was conducted using S-Plus (Insightful Corporation, Seattle, Washington, USA) software. Oestrogen and progesterone concentrations were assessed using a repeated measures analysis of variance with Statistica software for Windows (version 6.0; StatSoft, Tulsa, Oklahoma, USA).

RESULTS

General descriptive data

Table 1 presents the characteristics of the 17 subjects who completed the investigation. As oestrogen (p = 0.60) and progesterone (p = 0.50) concentrations did not vary throughout the study, data for male and female rowers were combined for all subsequent analyses.

On-water time trials were undertaken in cool (trial 1, mean (SD) 8.1 (0.8)℃, 59.3 (4.1)% relative humidity; trial 2, 7.0 (1.1)℃, 51.3 (6.4)% relative humidity; trial 3, 10.0 (2.4)℃, 39.2 (6.3)% relative humidity) and still (trial 1, 3.1 (0.9) km/h cross/head wind; trial 2, 1.2 (0.3) km/h cross/head wind; trial 3, 1.4 (0.8) km/h cross/head wind) conditions. Body mass was 3.9% lower (95% CI 3.5% to 4.4%) before $WT_{-4\%}$ than before UNR and did not vary according to sex (p = 0.95) or trial order (p = 0.75).

Weight loss in the 24 hours before $WT_{-4\%}$ was achieved by increasing training load (33.7 minutes, 95% CI 20.0 to 47.3; p<0.001) and restricting total food and fluid intake (−2520 g, 95% CI −2939 to −2102; p<0.001). Accordingly, fluid (−32.3 ml/kg, 95% CI −38.4 to −26.1; p<0.001), total energy (−97 kJ/kg, 95% CI −112 to −83; p<0.001), carbohydrate (−3.4 g/kg, 95% CI −4.1 to −2.7; p<0.001), fat (−0.6 g/kg, 95% CI −0.7 to −0.4; p<0.001), and protein (−1.1 g/kg, 95% CI −1.3 to −0.9; p<0.001) intakes decreased for $WT_{-4\%}$. Consequently when compared with UNR, both urinary osmolality (mean 0.49 osmol/kg, 95% CI 0.41 to 0.57; p<0.001) and serum osmolality (0.006 osmol/kg, 95% CI 0.001 to 0.012; p = 0.002) were increased before $WT_{-4\%}$, exceeding levels indicative of hypohydration.

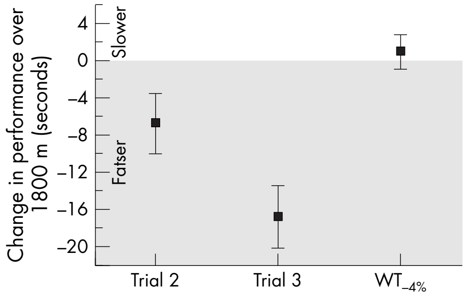

Figure 2 Effect of repeat trials (trial 2 and trial 3) and acute weight loss (4% over 24 hours, $WT_{-4\%}$) on 1800 m on-water time trial performance relative to trial 1. Values are mean difference (95% confidence interval) for 17 subjects.

Performance

On-water time trial performances improved throughout the investigation, with trial 2 (−6.8 seconds, 95% CI −3.5 to −10.0, p<0.001) and trial 3 (−16.9 seconds, 95% CI −13.6 to −20.3, p<0.001) faster than trial 1 (fig 2). After correction for the order effect, $WT_{-4\%}$ had only a small and statistically non-significant effect on performance (1.0 second, 95% CI −0.9 to 2.8; p = 0.29; fig 2) compared with UNR. Although the effect of sex was highly significant (45.0 seconds, 95% CI 36.1 to 53.8; p<0.01), there was no evidence of an interaction between sex and other fixed effects (p>0.05).

Biochemistry

Table 2 presents capillary biochemical data after exercise. Acute weight loss in the 24 hours before $WT_{-4\%}$ resulted in a 9.2% loss of plasma volume compared with UNR (95% CI −12.8% to −5.6%; p<0.001). No differences were evident between UNR and $WT_{-4\%}$ in blood pH (0.007, 95% CI −0.009 to 0.023; p = 0.37) or concentration of glucose (0.006 mmol/l, 95% CI −0.009 to 0.021; p = 0.42), bicarbonate (−0.069 mmol/l, 95% CI −0.232 to 0.094; p = 0.39), or lactate (0.014 mmol/l, 95% CI −0.184 to 0.211; p = 0.89) after exercise.

DISCUSSION

The primary finding of this investigation is that acute weight loss (4%) before the weigh in, when followed by aggressive nutritional recovery strategies, has only a small and statistically non-significant effect on on-water rowing performance. Although the performance implications of modest acute weight loss still need to be considered with regard to competition outcome, the absolute decrement in performance observed in this study is smaller than we have previously observed on the ergometer[4] and within the range associated with normal random variation in performance.[9]

Mechanism of performance decrement

The performance decrement associated with acute weight loss in lightweight rowers has been attributed in part[4] or whole[10] to the decrease in plasma volume that results from

Table 2 Capillary biochemical data after exercise

Variable	Trial UNR_1	UNR_2	$WT_{-4\%}$
pH	7.14 (0.06)	7.14 (0.08)	7.14 (0.07)
Glucose (mmol/l)	7.58 (1.19)	8.21 (1.05)	8.36 (1.00)
Bicarbonate (mmol/l)	12.38 (1.49)	11.64 (1.82)	11.84 (1.46)
Lactate (mmol/l)	13.72 (2.57)	12.21 (2.11)	12.45 (2.33)

Values are mean (SD).

What is already known on this topic

- The effect of acute weight loss on rowing ergometer 2000 m time trial performance appears to be small when aggressive nutritional recovery strategies are introduced in the two hour recovery period between weigh in and racing
- Despite this, existing data suggest that acute weight loss can still influence competition outcomes

What this study adds

- This study shows that the effect of acute weight loss on on-water rowing performance is even smaller than that previously identified on the ergometer
- The absolute performance decrement observed was largely within the range associated with normal random variation in performance

popular acute weight loss strategies. Although plasma volume was not measured immediately before time trials in this investigation, the plasma volume deficit immediately after weigh in was substantial. This suggests that full restoration of plasma volume in recovery was unlikely, as observed previously in these athletes, even when similar aggressive nutritional recovery strategies are introduced.[4] Other potential sources of performance decrement after acute weight loss include diminished muscle glycogen reserves and compromised thermoregulatory capacity, although neither is likely to have influenced performance in this investigation given the exercise duration[10] and environmental conditions. In addition, the performance implications of additional training undertaken in the 24 hours before the body mass restricted time trial (to assist with body mass management) cannot be discounted.

Although all of these mechanisms appear plausible, it is unlikely that only one mechanism resulting from acute weight loss limits rowing performance. Rather, an array of factors is probably responsible for any compromise in exercise performance associated with making weight, the relative importance of each factor depending on the method/s of acute weight loss plus skeletal muscle fibre type, the intensity, type, and duration of the performance effort, environmental conditions, and individual fitness capacity.[11]

On-water versus ergometer trials

The small effect of acute weight loss on on-water performance compared with the ergometer[4] may be a consequence of several factors. When lactate and heart rate responses are used as a guide to intensity, existing data suggest a greater physical load on the ergometer for performances at maximal intensity.[5] On-water absolute physical exertion may be somewhat constrained by the need to maintain biomechanical efficiency, limiting exertion near a threshold at which compromised cardiovascular and/or thermoregulatory functions influence performance. Alternatively, performance of on-water trials in a cool environment in this investigation may have limited any performance detriment associated with acute weight loss. Overall, cardiovascular strain is lower during exercising in the cold[12] and is thus less likely to be challenged sufficiently to compromise rowing performance, even in the presence of modest fluid deficits. Hypohydration associated with up to a 4% loss in body mass does not alter cardiovascular responses to moderately intense exercise undertaken in a cold environment.[12] Finally, on-water time trials were far less invasive than laboratory based trials;[4] fewer physiological variables were monitored, and athletes were free to adhere to their own warm up routines. Invasive testing procedures are believed to diminish concentration and increase variability in performance.[13]

Practical implications

International Federation of Rowing Association (FISA) guidelines state that ''weight loss in the 24 hours before racing should not exceed 1 kg''. Despite this, most lightweight rowers continue to make use of acute weight loss strategies to achieve specified body mass limits.[14] The FISA guidelines and those of the American College of Sports Medicine[1] were established in acknowledgement of the significant adverse consequences of making weight on competitive performance, physical health, and normal growth and development. Initial research on lightweight oarsmen indicated that the performance implications of acute weight loss were substantial.[10] However, more recent work by our group suggests that the implications of supervised, modest (4.3%) weight reduction are small when aggressive nutritional recovery strategies are enforced after weigh in.[4] The present investigation confirms that the effect on performance may be much smaller than expected. It is acknowledged that this may nonetheless influence competitive outcomes given that races are won and lost by narrower margins than those observed in this investigation.

Our results should be interpreted with caution. This investigation was undertaken in cool environmental conditions, unlike those that can be experienced by rowers during major regattas.[15] Slight variations in environmental conditions are acknowledged, although the performance implications of these are probably trivial. In addition, the performance (or other) implications of acute weight loss when repeated or sustained throughout a multi-day regatta remain unknown. Finally, we cannot discount the potentially fatal health implications of extreme acute weight loss (upwards of 10%) previously reported in some athletes in weight category sports.[16] Until these issues are addressed in the context of lightweight rowing, the recommendations for body mass management proposed by FISA remain the guidelines with which lightweight rowers should comply.

In summary, this investigation has shown that, contrary to our original hypothesis, body mass reductions of up to 4% over 24 hours, when combined with aggressive nutritional recovery strategies, can be undertaken with minimal impact on on-water rowing performance, at least in cool conditions (7–10℃). The effect of acute weight loss on repeat rowing performance in thermally challenging conditions, as occurs during major international regattas, warrants investigation before this body mass management strategy can be considered for lightweight rowers who do not easily achieve the specified body mass limits through traditional training and dietary interventions.

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