Beer as a Sports Drink? Manipulating Beer’s Ingredients to Replace Lost Fluid

Ben Desbrow, Daniel Murray, and Michael Leveritt

Purpose: To investigate the effect of manipulating the alcohol and sodium content of beer on fluid restoration following exercise. Method: Seven male volunteers exercised on a cycle ergometer until 1.96 ± 0.25% body mass (mean±SD) was lost. Participants were then randomly allocated a different beer to consume on four separate occasions. Drinks included a low-alcohol beer (2.3% ABV; LightBeer), a low-alcohol beer with 25 mmol×L–1 of added sodium (LightBeer+25), a full-strength beer (4.8% ABV; Beer), or a full-strength beer with 25 mmol×L–1 of added sodium (Beer+25). Volumes consumed were equivalent to 150% of body mass loss during exercise and were consumed over a 1h period. Body mass and urine samples were obtained before and hourly for 4 hr after beverage consumption. Results: Significantly enhanced net fluid balance was achieved following the LightBeer+25 trial (–1.02 ± 0.35 kg) compared with the Beer (–1.59 ± 0.32 kg) and Beer+25 (–1.64 ± 0.28 kg) treatments. Accumulated urine output was significantly lower in the LightBeer+25 trial (1477 ± 485 ml) compared with the Beer+25 (2101 ± 482 ml) and Beer (2175 ± 372 ml) trials. Conclusion: A low alcohol beer with added sodium offers a potential compromise between a beverage with high social acceptance and one which avoids the exacerbated fluid losses observed when consuming full strength beer. Keywords: rehydration, fluid balance, exercise, electrolytes, diuresis

During exercise, sweat output often exceeds fluid intake, producing a fluid deficit or hypohydration. Before recommencing exercise, the hypohydrated athlete is encouraged to consume beverages to restore all fluids and electrolytes lost (Sawka et al., 2007). This is because hypohydration impairs performance in both high intensity exercise (Armstrong et al., 1985), (Moquin & Mazzeo, 2001; Walsh et al., 1994) and endurance exercise (Ebert et al., 2007), as well as applied motor skills (Devlin et al., 2001) and some cognitive performance measures (Tomprowski et al., 2007), particularly when then level of hypohydration exceeds 2% of body mass. Consequently, it is important to investigate factors, such as drink volume and electrolyte concentration, that may influence a beverage’s ability to quickly restore fluid balance after exercise. Complete rehydration following exercise can be achieved when an individual consumes a sodium-enriched (~25mmol·L–1) beverage in an amount greater than the volume of sweat lost during exercise (Mitchell et al., 2000; Shirreffs et al., 1996). There is also evidence suggesting that increasing electrolytes (in particular sodium) can improve the rehydration potential of a beverage (Maughan & Leiper, 1995; Shirreffs et al., 1996). The practical application of this evidence is that athletes are more likely to replace fluid deficits if consuming sodium-containing beverages following exercise.

Beer has a long association with sport. Athletes have consumed beer as part of their postmatch celebration for decades (Burke & Read, 1988; Dietze et al., 2008). In many countries, consuming beer is a major part of the social sporting culture at all levels of adult participation and as such offers a medium by which to potentially influence fluid restoration following exercise. Yet, despite beer commonly being consumed in large volumes after exercise, there is little known of its capacity to replace fluid lost during exercise.

Clearly, the diuretic effect of alcohol (Eggleton, 1942; Murray, 1932) reduces beer’s potential to function as an optimal rehydration solution. Interestingly however, low alcohol beer (i.e., 1% and 2% alcohol) and nonalcoholic beer have similar rehydrating potentials following exercise-induced dehydration, whereas increasing the alcohol content to 4% appears to delay recovery and increases urinary losses (Shirreffs & Maughan, 1997). In addition, when the body is hypohydrated (following exercise) the diuretic effect of 1000 ml of 4% alcohol by volume beer was less than when fully rehydrated (Hobson & Maughan, 2010). These studies suggest that the diuretic impact of alcohol is less pronounced after exercise-induced hypohydration and that the percentage of alcohol is likely to influence beer’s rehydration potential.

Research on the effects of altering alcohol and sodium on the rehydration properties of beverages have

Desbrow and Murray are with the Griffith Health Institute, Griffith University, Queensland, Australia. Leveritt is with the School of Human Movement Studies, University of Queensland, Queensland, Australia
examine each ingredient independently, but, clearly, it would be useful to investigate the concurrent effect of altering the sodium and alcohol contents of beer on its potential to influence fluid balance following exercise-induced fluid loss. It is hypothesized that a reduced alcohol, higher sodium beer will reduce postexercise fluid losses compared with beers with higher concentrations of alcohol or without added sodium.

Methods

Subjects

Seven male healthy recreational athletes (29.7 ± 4.3 y, 86.56 ± 14.4 kg body mass, 184.4 ± 6.1 cm, VO2peak 56.6 ± 8.1 ml·kg⁻¹·min⁻¹ body mass; values are mean± SD) volunteered to participate as subjects in the current study. Subject’s average reported habitual alcohol intake in the 3 months before the study ranged from 2.5 to 150 g·week⁻¹. All subjects were fully informed of the nature and possible risks of the study before giving their written informed consent. The investigation was approved by the Human Research Ethics Committee of Griffith University.

Experimental Design

Each subject visited the laboratory on at least five occasions. The first visit was preliminary testing to confirm participants’ maximal exercise capacity. This was followed by the four experimental trials with the subject’s diet and exercise being standardized before each trial. Experimental trials consisted of exercise-induced mass loss (target 2.0% body mass) followed by consumption of a test beverage containing either a commercial low alcohol beer (XXXX light (Lion Nathan Ltd), 2.3% ABV) [LightBeer], the same commercial low alcohol beer with 25 mmol·L⁻¹ of added sodium [LightBeer+25], a standard commercial beer (XXXXX bitter (Lion Nathan Ltd), 4.8% ABV) [Beer], or the standard commercial beer with 25 mmol·L⁻¹ of added sodium [Beer+25]. Over a 1h period following exercise subjects consumed 150% of the total fluid volume lost during exercise. Measures of net fluid balance, urine production, breath alcohol concentration, and subjective ratings of gastrointestinal tolerance were collected hourly as dependent variables across a subsequent 4h rest period.

Preliminary Testing

Each subject performed an incremental test to exhaustion (VO2peak test) on an electromagnetically braked cycle ergometer (Lode Instruments, Groningen, The Netherlands) to determine VO2peak and Peak Sustainable Power Output (PPO). The VO2peak test protocol and the methods used for determining VO2peak and PPO have been previously described (Desbrow et al., 2007). Briefly, each test began at 100W and increased in 50W increments every 5 min until exhaustion. During the VO2peak test, which typically lasted between 30 and 35 min, each subjects’ expired air was continuously analyzed by a calibrated metabolic measurement system (MedGraphics, Minnesota, USA).

Training and Dietary Standardization

Experimental trials were separated by at least 7d and were conducted at the same time of the day in a stable laboratory environment (19 ± 2 °C, ~55% relative humidity). Subjects were instructed to refrain from consuming alcohol 48h and caffeine-containing substances for 12 h before each experiment. Subjects were also asked to refrain from heavy training 24h before each trial and any light training was to be completed by 1200h the day before the experimental trials. Food and exercise diaries were used to examine compliance to these procedures. On arrival at the laboratory (0600h) subjects undertook a breath alcohol compliance check (Alcolizer Technologies Inc, Brisbane, Australia) and a urine specific gravity (USG) measure. In the event of a USG recording >1.02 subjects were asked to consume a small amount of water (range 500–1000 ml) until a USG ≤1.02 could be established. On confirmation of euhydration a standard breakfast was then supplied which provided approximately 30 kJ·kg⁻¹ body mass of energy, 1g·kg⁻¹ body mass of carbohydrate, 3.2 mg·kg⁻¹ body mass of sodium and 125 ml of fluid. The breakfast was designed to provide participants with some food for the subsequent 5- to 6-hr testing period while minimizing fluid and sodium intakes.

Experimental Protocol

Following breakfast a 30-min rest period was taken before the subjects were instructed to empty their bladder as completely as possible and a nude body mass was measured using a calibrated electronic scale to the nearest 10 g (AND Mercury DX6000). Subjects then commenced exercise dressed in shorts, shoes and disposable coveralls (Kimberly-Clarke Worldwide Inc.) designed to increase the heat and subsequent sweat losses while cycling. Exercise intensity was initially set at 60% of the subject’s peak power output aiming to produce a 2% reduction in the subject’s body mass. For their first trial subject’s cycled for 45 min before dismounting, drying with a towel and taking a nude body mass. Subsequent nude body mass were taken at regular intervals until ~1.8% of the subject’s initial body mass was lost at which point the subject stopped cycling to allow the remainder of mass loss to occur throughout the cool down. During all subsequent trials subjects exercised for ~10 min less than the total exercise time from the first trial before the first nude body mass was collected. If ~1.8% body mass deficit was not achieved subjects were instructed to continue exercising until this goal was reached. A rest period of 30 min occurred after the exercise phase to allow subjects to have a cool shower, return to a cool environment and rest. On completion of this period a final nude body mass was taken to determine the volume of fluid required for consumption during the rehydration phase.

Over the next 60 min, the subjects ingested one of the rehydration beverages; the order of treatment was randomized using an incomplete Latin square design. The entire beverage volume, equal to 150% of the change in body mass, was divided into four equal parts, each
of which was consumed over a 15-min period. For the subsequent 4-hr observation period, subjects remained within the laboratory, and were seated except for essential movements. Trials were conducted in a stable laboratory environment (22 ± 2 °C, 60–70% relative humidity).

**Test Beverage Preparation**

The beverages chosen were manufactured by one commercial brewer and purchased at the same time, to minimize the influence of additional and/or different ingredients throughout production. The manufacturer’s reported sodium content of the commercial products were between 3–5 mmol×L⁻¹ (subject to slight seasonal variation). The additional sodium was added, in form of sodium chloride, before consumption by one of the research team (DM).

**Subjective Measures**

Questionnaires were conducted during the rehydration phase of the study looking at both palatability and gastrointestinal (GI) symptoms. The palatability questionnaire was administered with the second and last beverages and consisted of ratings of overall palatability, liking, saltiness, sweetness, and tartness. The GI questionnaire consisted of rating of nausea, bloating, heartburn, flatulence, belching, abdominal rumbling, and hunger and was conducted before the first beverage (baseline), at 15 min following the last drink and at hourly intervals until the end of the observation period. All questionnaires responses were quantified using a 20-point scale (GI Scale 0 = No symptoms to 20 = Most severe; Palatability Scale 0 =Total dislike to 20 = Like, extremely).

**Fluid Balance and Breath Alcohol Measures**

Total urine loss was calculated from the total accumulated urine output in the period from the commencement of drinking until the end of the observation period (i.e., 5 h total). Participants were permitted to urinate as required throughout the observation period. Urine per hour was calculated following requested voiding at the conclusion of each hour throughout this 5-h period. Net fluid balance was calculated by subtracting the body mass (post voiding) from the initial body mass. When used across an acute time period, it is proposed that this noninvasive parameter will take into account urinary losses, sweat loss and other insensible losses, and arrive at the value of complete hydration status (Armstrong, 2005).

Breath alcohol concentrations were analyzed using a police grade Alcolizer LE breathalyser (Alcolizer Pty Ltd., Brisbane, QLD, Australia), which had been recently calibrated by the manufacturer. All breathalyser measurements were taken in duplicate, with a triplicate measure recorded if readings differed by ≥ 0.005%. The measures were averaged to provide the final assessment of BrAC. Previous research from our laboratory has indicated the intertrial coefficient of variation for the breathalyser is 2.5% (Irwin, Goodwin, Leveritt, Davey, & Desbrow, 2012). Participants were not informed of their BrAC measures until after completion of the entire study. As described, an initial breath alcohol sample was taken to confirm participants reported to the laboratory having completed a period of alcohol abstinence. The second breath alcohol sample occurred 15 min after completing the rehydration phase. This short period was used to avoid contamination from alcohol that may have remained within the mouth. Further breath samples were collected at 1, 2, 3, and 4 hr throughout the observation period. Results are expressed as a percentage.

**Statistical Analysis**

Statistical analysis was conducted using Prism 5.03 for Windows (Graphpad Software Inc, La Jolla, CA, USA). One way repeated-measures ANOVA was used to determine any variation between trial on initial body weight, percentage dehydration, exercise time, drink palatability, and total urine volume. Two-way (treatment and time) repeated-measures ANOVA was used to compare hourly urinary volume total, net fluid balance and gastrointestinal comfort. Post hoc analysis (LSD) was performed on all significant F ratios. Significant differences were accepted when p ≤ .05. All data are reported as means± SD.

**Results**

**Standardization Procedures and Exercise Induced Dehydration**

All participants arrived at the laboratory and reported compliance with the pretrial dietary and exercise control conditions. Participants began each trial without detectable breath alcohol and in a hydrated state according to the USG threshold. A small but statistically significant variation in initial body mass was evident between the Beer and Beer+25 trials (LightBeer+25 = 86.1 ± 14.6 kg, LightBeer = 86.3 ± 14.3 kg, Beer+25 = 87.1 ± 14.0 kg, Beer = 86 ± 14.6 kg, p = .023). Despite this, participants were successful in achieving similar levels of hypohydration after the exercise protocol in each of the four conditions (LightBeer+25 = 1.93 ± 0.29%, LightBeer = 2.0 ± 0.25%, Beer+25 = 1.93 ± 0.28%, Beer = 1.99 ± 0.23%, p = .93). In addition, the mean exercise time required to induce the dehydration did not differ between trials (LightBeer+25 = 74 ± 13 min, LightBeer = 79 ± 15 min, Beer+25 = 77 ± 14 min, Beer = 73 ± 16 min, p = .86).

**Alcohol Consumption**

Volumes of beer consumed varied between subjects according to their initial bodyweight and degree of hypohydration. The mean volume of beer consumed was not different between trials (LightBeer+25 = 2.47 ± 0.43 l, LightBeer = 2.57 ± 0.41 l, Beer+25 = 2.50 ± 0.39 l, Beer = 2.54 ± 0.29 l, p = .96). This equated to an alcohol intake of 57 ± 9 g (LightBeer+25), 59 ± 9 g (LightBeer), 120 ± 19 g (Beer+25), 122 ± 14 g (Beer) per trial. Due to volume tolerance issues some subjects required slightly
longer than the allocated 1h time period to consume test beverages. The longest required drinking period for all trials was 75 min. On all trials where >60min was required for drink consumption all dependent measures were taken relative to the commencement of drinking. One trial had to be repeated due to fluid loss via emesis.

Urine Volume and Fluid Balance

The total urine volumes for each trial are shown in Figure 1 and the volumes of urine produced per hour for each trial are shown in Figure 2. Peak urine output occurred throughout the second hour following alcohol ingestion on all trials with the exception of LightBeer+25 where peak urine output occurred throughout the first hour. No statistically significant difference in hourly volumes were observed despite the difference between LightBeer+25 and Beer+25 trials approaching significance 2 hr after the cessation of drinking (p = .10). Whole body net fluid balance values for each trial are shown in Figure 3. A number of subjects requested to urinate within the drinking period, consequently the postdrinking net fluid balance values are below what could be anticipated given the volume of fluid ingested.

All experimental treatments concluded with participants in a state of negative fluid balance relative to preexercise values (LightBeer+25 trial = –1.02 ± 0.40 kg, LightBeer = –1.24 ± 0.35 kg, Beer+25 = –1.59 ± 0.32 kg, Beer = –1.64 ± 0.28 kg). The consumption of beer with higher levels of alcohol had significantly negative effect on net fluid balance (LightBeer vs. Beer –0.4kg of body mass, p = .04, LightBeer+25 vs Beer+25 –0.57kg of body mass, p < .01). The net fluid balance results are largely accounted for by higher urine production when consuming higher alcohol beers (LightBeer = 1757 ± 412 ml vs Beer = 2175 ± 372 ml, p = 0.09, LightBeer+25 = 1477 ± 485 ml vs. Beer+25 = 2101 ± 482 ml p = .014). The addition of sodium to low alcohol beer tended to reduce the average total urine output (LightBeer+25 = 1477 ± 485 ml vs. LightBeer = 1757 ± 412 ml), yet the difference was not statistically significant when analyzed as total urine or net fluid balance (total urine p = .25, net fluid balance p = .26). At higher concentrations of alcohol (i.e., Beer vs. Beer+25) the addition of sodium had no obvious influence on total urine production or net fluid balance (total urine p = .75, net fluid balance p = .77). When considered in combination, the reduction of alcohol and the addition of sodium (i.e., LightBeer+25 vs. Beer) significantly reduced urine volumes and improved net fluid balance (total urine p < .01, net fluid balance p < .01). The effect on net fluid balance was evident within 3 hr of observation.

Breath Alcohol Concentrations

The mean breath alcohol measures for each of all trials are shown in Figure 4. Peak breath alcohol values were recorded 15 min after the cessation of drinking on all trials. As expected, the higher concentration beers produced significantly greater breath alcohol values (p < .01) compared with the lower concentration beer trials. There were no differences in hourly breath alcohol values observed between trials with similar alcohol concentrations (i.e., LightBeer vs. LightBeer+25 or Beer vs. Beer+25, p > .05 for all comparisons).

![Figure 1](#) — The total urine volumes following the 5-hr observation period. a) Significant difference between LightBeer+25 vs Beer+25 (p = .014), b) Significant difference between LightBeer+25 vs Beer (p < .01). No other statistically significant differences observed.
Figure 2 — Volumes of urine produced per hour throughout the 5-hr observation period. No statistically significant differences observed.

Figure 3 — Net fluid balance calculated by change in body mass throughout the 5-hr observation period. a) Significant difference between LightBeer+25 vs. Beer+25 $p < .01$ at 3 hr and 4 hr, b) Significant difference between LightBeer+25 vs Beer $p < .01$ at 3 hr and 4 hr, and c) LightBeer vs Beer ($p = .04$). No other statistically significant differences observed.
Subjective Ratings

No statistically significant differences were observed for any gastro-intestinal rating other than hunger which increased significantly throughout the observation period independent of drink treatment (mean of all trials 6.4 ± 5.9 before drinking vs. 15.9 ± 5.7 following 4-hr observation \( p < .01 \)). Ratings of drink saltiness increased to the same extent for both drinks containing added sodium and was independent of time (LightBeer and Beer 5.6 ± 4.7 vs. LightBeer+25 and Beer+25 12.7 ± 4.4 following 2nd drink, \( p < .01 \)). Despite the change in taste no other statistically significant differences were observed for any other palatability rating.

Discussion

The current investigation examined the concurrent effect of altering the sodium and alcohol content of commercial beer on its potential to influence fluid retention following exercise-induced fluid loss. The principle finding supports our hypothesis, in that, reducing the alcohol concentration and raising the sodium content of beer resulted in significantly greater post exercise fluid retention compared with drinking a commercial full strength beer.

Reducing the alcohol content of beer alone had a significant positive impact on eventual net fluid balance. The only other previous experiment to have investigated the impact of different doses of alcohol on fluid retention following exercise observed similar results (Shirreffs & Maughan, 1997). Despite only including 6 participants this investigation indicated that beverages containing ≤ 2% ABV are likely to have a negligible diuretic effect compared with a 4% ABV beverage when consumed following exercise (Shirreffs & Maughan, 1997). Collectively, it appears then, that beers containing ≥ 4% alcohol are likely to induce greater urine outputs, impairing an individual’s capacity to replace fluid losses.

The addition of sodium to low alcohol beer appeared to induce a fluid conservation that was not evident when the same amount of sodium was added to the full strength beer. While this result failed to reach statistical significance, when sodium was added to the low alcohol beer participants conserved on average a further ~280 ml of fluid. When similar amounts of sodium are added to non-alcoholic fluids provided following exercise significantly greater fluid retention has been observed (Maughan & Leiper, 1995). Thus, it appears that at lower concentrations of alcohol (~2% ABV) the addition of sodium may continue to contribute to improving fluid retention. The potential of sodium, when added to low alcohol beer, to produce effects in a dose dependent manner is yet to be elucidated.

All beverage treatments failed to completely restore fluid balance across the 4-hr observation period suggesting that beer, irrespective of ingredient profile, is an undesirable postexercise fluid. However, the influence of any beverage ingredient manipulation on rehydration

Figure 4 — Breath alcohol concentrations throughout the 5 hr observation period. No statistically significant differences observed between beverages with the same alcohol concentration.
relative to an absolute measure (such as return to euhydration) needs to be done with caution as the absolute urine output during the observation period is likely be influenced by the drinking rate (bolus vs. metered) used to replace the lost fluid. Increases of ~40% in total urine production have been reported with acute large volumes of fluid (bolus drinking) thought primarily due to an endocrine mediated exacerbation in diuresis (Jones et al., 2010; Mitchell et al., 1994). Given the rapid drinking rates used in the current study, a relative comparison between treatments is likely to provide the most reliable interpretation of the influence alcohol ± added sodium has on postexercise fluid retention.

Changes in beverage sodium content failed to influence measures of breath alcohol throughout the observation period. The similarity in breath alcohol measures suggests that the addition of sodium to beer does not markedly influence the blood alcohol response curve; although more a rigorous pharmacokinetics investigation would be required for verification. The addition of sodium also failed to influence measures of palatability or gastro-intestinal tolerance suggesting that mild sodium modifications within beer are likely to have little influence on ad libitum consumption.

Clearly, many athletes are likely to engage in the consumption of beer following exercise regardless of the negative health implications. A low alcohol beer with added sodium may provide a compromise to the hypohydration athlete following exercise in that it is a beverage with high social acceptance and palatability while avoiding the exacerbated fluid losses observed when consuming full strength beer. The emphasis of beverages with lower alcohol contents may also act as a useful harm minimization strategy aimed at the recovering athlete.

In summary, a reduced alcohol beer with added sodium will reduce postexercise fluid losses compared with full strength commercial beer.

Conflict of Interest

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References


