The Impact of Sugar-Based Beverages on Hydration Status in Various Work Conditions: A Systematic Review

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Abstract

Body water is essential to sustain the cardiovascular system, thermoregulatory system and support cellular homeostasis. According to the Indian Dietary Guidelines, ~8 glasses (2000 ml) of water per day is adequate to maintain hydration in healthy individuals. However, this theory is subjected to a broad range of interpretation by different individuals. Plain water is often assumed as the only source that fulfils daily fluid requirements, the contribution of other beverages like coffee, tea, milk and Sugar-Based drinks towards fluid balance is often suspended. In recent years, an increase in the intake of Sugar-Based beverages have been recorded worldwide. Similarly, given the potentially large consumption of Sugar-Based beverages in India, it is important to understand their impact on everyday hydration. It remains unclear whether the intake of Sugar-Based beverages contributes to hydration or merely causes health concerns. This is the first Indian review to study the impact of Sugar-Based beverage consumption on hydration status of individuals. In this systematic review, characteristics of 16 studies were considered which include 12 Randomised Controlled Trials (RCTs), 1 Clinical Controlled Trial (CCT) and 3 Experimental Studies (ES). Our main findings suggest: (1) A positive correlation between the consumption of Sugar-Based drinks and maintenance of fluid balance and hydration, (2) Additional energy and performance related benefits of Sugar-Based drinks during dehydration conditions and (3) Up to 6% concentration of sugar in beverages improves water absorption rates in intestines.

Keywords: Sugar, Carbohydrate, Hydration, Fluid Balance, Dehydration, Beverages

Introduction

Water counts to be 70% of the total body weight in humans. Lack of availability or imbalance of fluids in the body can seriously jeopardize health and the ability to function. "Normal" hydration is usually achieved with a wide range of water intakes by sedentary as well as active people.¹ According to the Indian Dietary Guidelines, approximately eight glasses (2000 ml) of water per day is adequate to maintain hydration in healthy individuals. In reality, recommended daily intake of drinking fluid may not only be achieved through water, but also through other sources such as coffee, tea, milk and Sugar-Based beverages such as soft drinks and juices.² To support this EFSA guidance panel suggests that 70-80% water intake is provided by beverages along with water.

Sugar-Based beverages when consumed as part of the recommended daily fluid intake, might contribute towards maintaining fluid balance and ensuring good hydration as well as optimal physical performance. This is because these products typically contain approximately 90% of water.³ They are also associated with increased energy intake due to the presence of sugar.⁴ According to the data from India Sugar Trade Industry 2013,
India is the second largest consumer of sugar in the world. In recent years, an increase in the intake of sugars from Sugar-Based beverages has been recorded. Easy availability of these drinks in rural as well as urban areas has significantly contributed to higher sugar consumption.5

Despite its popularity, consumption of excessive sugar is considered to be a health concern and has been viewed as a major contributor to rising prevalence of childhood obesity,6 metabolic syndrome,7 diabetes8 and increased risk for cardiovascular diseases.8

It still remains unclear whether the intake of Sugar-Based beverages contributes to hydration or merely causes health issues. It is, therefore, essential to understand the impact of sugar consumption and its role in contributing towards optimal fluid balance. In this present study, we investigated the evidence of the association between consumption of Sugar-Based drinks and hydration status in various scenarios.

Materials and Methods

Search Strategy and Selection Criteria

The PubMed database was searched for prospective cohort studies that evaluated the association between sugar consumption and hydrating effect. The search was performed by using the keywords “sugar”, “glucose”, “carbohydrate”, “calorie” or “caloric”, each combined with “hydration”, “rehydration”, “dehydration”, “urine volume”, “diuresis”, “diuretic” or “fluid balance”, with optional keywords “aerated beverages”, “aerated drinks”, “soft drinks” and “cola”. No publication date range was imposed. Relevant articles were selected using a 2-step approach. First step comprised of screening the titles and abstracts of the identified references in order to exclude articles that did not deal with the topic of interest. Second step included further analysis of the full-text screened articles to exclude articles that were non-English, had no human subjects and those that were repetitive. The references of the remaining articles were manually screened to locate further relevant studies and articles.

Data Collection and Analysis

A total of over 20,000 articles were identified using PubMed. Upon screening the titles and abstracts of the identified articles, only 175 articles were included for further analysis. 165 articles were excluded after second screening. Upon manual screening of references within the remaining 10 articles, 6 additional articles were identified and a sum total of 16 full text articles were included in our analysis. For each included study, data was extracted by all authors independently. Any discrepancies were resolved by discussion. Articles were assessed using the following variables: author(s), country, year of publication, number of patients, type of study and methods employed, demographics, clinical findings and conclusion on whether or not the study favours an association between consumption of Sugar-Based drinks and improved hydration.

Study Characteristics

The characteristics of 16 studies were considered. These included 12 Randomised Controlled Trials (RCTs) (Table 1), 1 Clinical Controlled Trial (CCT) (Table 1) and 3 Experimental Studies (ES) (Table 2).

Results

Randomised Controlled Trials (RCTs)

• Normal Setting

In a study by Grandjean AC et al.2 (n=18), various combinations of beverages containing carbonated, caffeinated caloric and non-caloric colas, coffee and carbonated, non-caffeinated, citrus soft drinks were compared to measure fluid balance amongst individuals. As indicators of hydration status, loss in body weight (0.30%) and change in 24-hour urine volume were found to be clinically insignificant in all combinations, revealing that Sugar-Based drinks did not affect the hydration status.

• Exercise and Sports Performance

In a study by Lambert CP et al.9 (n=8), various combinations of carbonated, carbohydrate, non-carbonated and non-carbohydrate beverages were compared to assess the fluid replacement capacity and recovery post-exercise induced dehydration amongst individuals. As indicators of hydration status, plasma volume changes, plasma protein concentrations (p >0.05), % body weight loss and total urine volume were found to be statistically insignificant amongst all the combinations, revealing that Sugar-Based carbonated drinks were as effective as non-sugar non-carbonated drinks.

In a similar study by Dougherty KA et al.10 (n=15), carbohydrate (6%) electrolyte beverages were compared with non-carbohydrate flavoured water to assess their effect on hydration status in individuals while performing sports. Sports performance through basketball shooting rate, total sprint time and total defensive drill times was significantly improved in those who consumed the carbohydrate (6%) electrolyte beverages, revealing that Sugar-Based drinks are more effective than water at maintaining fluid balance and state of hydration whilst improving sports performance.

When Nielson B et al.11 (n=15) compared sugar beverages
with sodium and potassium beverages to assess their effect on fluid balance post-exercise, it was revealed that the change in plasma protein concentration and reduction in work capacity (20%) during the supramaximal exercise test were similar amongst these beverages, suggesting similar impact of all beverages on the hydration status post-exercise.

Additionally, while comparing the effect of carbohydrate (7%) beverages and placebo during high-intensity exercise by Wilber RL et al.12 (n=10), it was revealed that Sugar-Based drinks improved performance (29.4%) and increased blood glucose concentration in individuals as compared to non-sugar placebo. A similar study by Nicholas CW et al.13 (n=9), revealed that carbohydrate-electrolyte (6.9%) beverages improved performance endurance (33%) and delayed fatigue before and during high-intensity exercise as compared to non-sugar placebo. A study by Tsintzas OK et al.14 (n=11) showed that two different concentrations of carbohydrate-electrolyte (5.5% and 6.9%) beverages provided better endurance capacity and delayed time to exhaustion by approximately 12-15 minutes during the first hour of exercise, compared to water alone. A study by Fallowfield JL et al.15 (n=12) further reiterated that carbohydrate-electrolyte (6.9%) beverages improve performance endurance and delay time to exhaustion by approximately 22.2 minutes post exercise, compared to non-sugar placebo. A study by Wong SH et al.16 (n=9) suggested that carbohydrate-electrolyte (6.9%) beverages along with improving performance endurance and delaying time to exhaustion by approximately 24.3 minutes, also displayed fluid balance that was comparable to no-sugar beverages. A study by Watson P et al.17 (n=24) assessed the effect of various combinations of carbohydrate-electrolyte beverages with varying sugar levels post-exercise in different temperatures. It was revealed that 4% and 6% Sugar-Based drinks at low temperatures (10°C) and 6% Sugar-Based drinks at high temperatures (30°C), improved exercise capacity and delayed time to exhaustion compared to that of no-sugar placebo.

A study by Kamijo Y et al.18 (n=7) assessed the effects of high-carbohydrate, low-carbohydrate and no-sugar electrolyte beverages during recovery from exercise-induced dehydration and revealed that high-carbohydrate electrolyte beverages had faster increase in plasma volume, smaller accumulation of urine volume, higher plasma glucose and serum insulin levels and greater renal Na+ absorption rate, as compared to no-sugar placebo.

- **Industrial Environment**

According to a study by Clapp AJ et al.19 (n=6) which compared the effect of carbohydrate-electrolyte drinks with water in providing adequate hydration to workers, it was revealed that individuals consumed lesser amount of fluids and experienced greater amounts of weight loss on water as opposed to carbohydrate-electrolyte drinks. The study suggested that Sugar-Based drinks produce better hydration than water alone in industrial environments.

**Clinical Controlled Trial (CCT)**

In a study by Ryan AJ et al.20 (n=9), various combinations of carbonated and non-carbonated carbohydrate beverages were compared to assess their effect on individuals during prolonged exercise. All beverages exhibited similar results on gastric emptying (p > 0.05), ad-libitum drinking (p < 0.05), sweat rate, loss of body weight and fluid replacement by ad libitum drinking, suggesting that carbonation and varying sugar-levels have the same influence on gastric emptying and ad-libitum drinking as beverages without carbonation.

**Experimental Studies (ES)**

A study by Gisolfi CV et al.21 (n=8) compared various Sugar-Based beverages of varying concentrations to assess their effect on water absorption from intestines. It was revealed that different types of sugar-(up to 6%) based beverages increased water absorption rate compared to no-sugar control.

In a study by Evans GH et al.22 (n=6), when the Sugar-Based beverages were compared with no-sugar placebo to assess their effect on individuals post exercise, it was revealed that the Sugar-Based beverages had higher fluid retention (46 ± 9% and 40 ± 14%, for 2% and 10% respectively) compared to placebo (27 ± 13%) and that the drink with highest concentration (10%) of carbohydrate exhibited longest euhydration. This suggested that Sugar-Based beverages with higher concentrations are more effective at restoring and maintaining hydration status during rehydration as compared to those with low concentration.

An Indian study by Khanna GL et al.23 (n=10) revealed that carbohydrate-electrolyte (5% and 12.5%) beverages improved performance endurance (51%), enhanced lactate removal and delayed fatigue during exercise and recovery.

**Discussion**

Our main findings suggest: (1) A positive correlation between the consumption of Sugar-Based drinks and maintenance of fluid balance and hydration, (2) Additional energy and performance related benefits of Sugar-Based drinks during dehydration conditions and (3) Up to 6% concentration of sugar in beverages improves water absorption. Since plain water is often assumed as the only source that fulfils daily fluid requirements, the contribution of other beverages...
towards fluid balance is often suspended rates in intestines.

Sugar-Based carbonated drinks were identified to be similar to non-sugar drinks, non-carbonated drinks and water in maintaining hydration, under post-exercise induced dehydration conditions.\(^2\) It was also shown that the presence of carbonation in Sugar-Based drinks did not influence ad-libitum or at-will drinking and gastric emptying.\(^11\) Gastric emptying is usually regulated by the caloric content of the fluid and contrary to these results, its rate is generally believed to be less rapid in a sugar drink as compared to water.\(^13\) Therefore, disregarding consumption of Sugar-Based carbonated drinks due to lack of hydration is not substantiated by this study.

Non-carbonated Sugar-Based electrolytes have also been significantly efficient than water in contributing towards fluid balance in post-exercise induced dehydration conditions as well as in industrial settings with workers operating at low metabolic rates over longer periods of time.\(^11\) Furthermore, another study demonstrated that energy-dense, hypertonic Sugar-Based beverages may be more effective at restoring fluid balance and maintaining euhydration status for longer periods as compared to hypotonic, low-sugar or no-sugar drinks\(^21\).

In addition to this, a study showed that hypertonic Sugar-Based drinks had similar impact on hydration as potassium and sodium drinks.\(^22\) These findings are crucial as addition of electrolytes such as sodium and potassium in beverages have been shown to play a major role in restoring fluid balance through up-regulation of water absorption and promotion of ad-libitum fluid intake.\(^24\) Therefore, comparable results between Sugar-Based drinks and potassium and sodium drinks, discredit the notion that caloric beverages lead to fluid imbalance and in fact promotes its efficiency.

Additional benefits of Sugar-Based drinks such as enhanced exercise performance, improved exercise capacity, delayed onset of fatigue, enhanced lactate removal and faster recovery from dehydration, surfaced while assessing the outcomes of several studies.\(^13\)\(^24\)

During exercise, the primary goal of fluid replacement is to prevent dehydration and to supply adequate energy source for the liver and contracting skeletal muscles. Therefore, the concentration of Sugar-Based beverages is a determining factor to establish how much fluid and energy is delivered to the intestines for absorption\(^21\). The studies in this review include beverages with sugar concentration ranging between 4% and 10%.

While evaluating the absorption pattern of the Sugar-Based drinks, it was highlighted that sugar concentration of up to 6% in different forms of carbohydrate beverages (glucose, fructose, maltodextrin and corn syrup solid), exhibits similar effect on water absorption from intestines. There was also a strong correlation found between increasing sugar content in the electrolyte beverages and enhanced renal Na\(^+\) reabsorption.\(^19\)

Not accounting for the studies that included ad-libitum drinking of beverages, individuals consumed equal quantities of beverages that were randomly assigned to them. While some consumed plain, flavoured and no-sugar water which amounts to almost 100% water, it has to be noted that the remaining beverages, with carbonation and added sugar, would contain lesser content of water. If adjustments based on the available water content were to be made, the volumes of other beverages consumed by individuals would in fact increase. Therefore, studies providing fluids based on equal delivery of water content would further elucidate the ability of these Sugar-Based beverages to maintain adequate hydration status.\(^2\)

Further to our analysis, we establish that robust Indian trials consisting of larger sample population, comprehensive data, rigorous investigation and in-depth outcome measures would quantify our hypothesis more definitely in linking the consumption of Sugar-Based beverages with hydration status. Therefore, additional focus on this research area is required.

Conclusion

This is the first Indian review to study the impact of sugar consumption on hydration status of individuals. Given the multiple sources of hydration within the Indian diet, it is noteworthy that consumption of a single source may not take into account all the required nutrients that contribute towards optimal fluid balance. For healthy nutrition, it is therefore, important to incorporate various different sources of fluids in everyday diet. Combined, our results suggest that Sugar-Based beverages display beneficial effects during exercise induced dehydration or in industrial environments with prolonged work hours. Based on this evidence, it would not be prudent to recommend our population to completely reject Sugar-Based drinks altogether on the grounds of their diuretic effects. Future confirmatory trials with bigger sample population, longer time periods and specific emphasis on quantifying safe amounts of sugar content in drinks are required to set the context more affirmatively.
## Table 1. RCTs and CCT on the association between consumption of Sugar-Based drinks and improved hydration

<table>
<thead>
<tr>
<th>Author(s)/Publication Date</th>
<th>Country</th>
<th>Demographics</th>
<th>Beverages used/compared</th>
<th>Main Finding</th>
<th>Association between Sugar-Based drinks and hydration status as interpreted by the authors</th>
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<tbody>
<tr>
<td><strong>Randomised Controlled Trials (RCTs)</strong></td>
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<tr>
<td>1 Grandjean AC et al. (2000)²</td>
<td>USA</td>
<td>18 healthy males aged 24-39 years</td>
<td>1. Water 2. Water AND caffeinated, carbonated cola (CCC) 3. Water AND caffeinated, carbonated non-caloric cola (CCNC) 4. Water AND CCC AND CCNC AND Instant Coffee 5. Water AND carbonated citrus non-caffeinated soft drink</td>
<td>As indicators of hydration status, loss in body weight (0.30%) and change in 24-hour urine volume was statistically insignificant amongst all combinations</td>
<td>Sugar-Based drinks have no significant negative effect on the hydration status, therefore disregarding them as a part of daily fluid intake is not substantiated</td>
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<tr>
<td>2 Lambert CP et al. (1992)⁹</td>
<td>USA</td>
<td>8 healthy males aged 22-34 years</td>
<td>1. Carbonated (10%) glucose-fructose 2. Carbonated non-carbohydrate 3. Non-carbonated (10%) glucose-fructose 4. Non-carbonated non-carbohydrate</td>
<td>As indicators of hydration status, plasma volume changes, plasma protein concentrations (p &gt;0.05), % body weight loss and total urine volume were statistically insignificant amongst all the combinations</td>
<td>Sugar-Based (10%) carbonated drinks are as effective as non-sugar non-carbonated drinks for causing fluid replacement and providing adequate hydration post-exercise</td>
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<tr>
<td>3 Dougherty KA et al. (2006)¹⁰</td>
<td>USA</td>
<td>15 healthy males aged 12-15 years</td>
<td>1. Carbohydrate (6%) electrolyte 2. Flavoured non-carbohydrate water</td>
<td>Sport performance through basketball shooting rate (60 ± 8%; p= 0.003), total sprint time (76 ± 9 sec; p= 0.04) and total defensive drill times (77 ± 10 sec; p= 0.006) was significantly improved in those who consumed carbohydrate-electrolyte drink</td>
<td>Sugar-Based (6%) electrolyte drinks are more effective than water at enhancing sports performance while maintaining fluid balance and hydration</td>
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<td>4</td>
<td>Nielsen B et al. (1986)</td>
<td>Denmark</td>
<td>6 healthy males aged 18-32 years</td>
<td>1. Glucose (2.5%) 2. Potassium drink 3. Sodium drink 4. Sugar drink (9% glucose plus fructose)</td>
<td>Change in plasma protein concentration and reduction in work capacity (20%) during the supramaximal exercise test were similar amongst different drinks.</td>
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<td>5</td>
<td>Wilber RL et al. (1992)</td>
<td>USA</td>
<td>10 healthy males aged 26-34 years</td>
<td>1. Carbohydrate (7%) drink 2. Placebo</td>
<td>Exercise performance was enhanced (29.4%) and blood glucose concentration was significantly greater by carbohydrate drink as compared to placebo</td>
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<td>6</td>
<td>Nicholas CW et al. (1995)</td>
<td>UK</td>
<td>9 healthy males aged 24-26 years</td>
<td>1. Carbohydrate-electrolyte (6.9%) 2. Non-carbohydrate with artificial sweetener- aspartame</td>
<td>Exercise performance was enhanced through delayed fatigue and improved endurance running capacity (33%) by carbohydrate-electrolyte drink as compared to placebo</td>
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<td>7</td>
<td>Tsintzas OK et al. (1996)</td>
<td>UK</td>
<td>11 healthy males aged 25-29 years</td>
<td>1. Carbohydrate-electrolyte (5.5%) 2. Carbohydrate-electrolyte (6.9%) 3. Water</td>
<td>Time to exhaustion for carbohydrate-electrolyte drinks was higher (by 12-15 mins; p &lt; 0.05) and performance time was longer compared to water alone</td>
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<td>8</td>
<td>Fallowfield JL et al. (1995)</td>
<td>UK</td>
<td>12 healthy males and 4 healthy females aged 25-30 years</td>
<td>1. Carbohydrate-electrolyte (6.9%) 2. Placebo</td>
<td>Time to exhaustion for carbohydrate-electrolyte drink was higher (by 22.2 mins; p &lt; 0.05) compared to placebo</td>
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<tr>
<td>Study</td>
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<td>Interventions</td>
<td>Findings</td>
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<td>9</td>
<td>Wong SH et al. (2000)</td>
<td>Hong Kong</td>
<td>9 healthy males aged 25-28 years</td>
<td>1. Carbohydrate-electrolyte (6.9%) 2. Carbohydrate and electrolyte-free sweetened placebo</td>
<td>Both drinks had comparable positive fluid balance during recovery. For the carbohydrate-electrolyte drink, time to exhaustion was higher (by 24.3 mins; p &lt; 0.05) and blood glucose concentration was also higher, compared to placebo.</td>
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<tr>
<td>10</td>
<td>Watson P et al. (2012)</td>
<td>UK</td>
<td>24 healthy males aged 20-24 years</td>
<td>1. Carbohydrate-free 2. Carbohydrate (2%) 3. Carbohydrate (4%) 4. Carbohydrate (6%)</td>
<td>Time to volitional exhaustion in low temperatures (10°C) was longer in 4% (121 mins) and 6% (122.4 mins) carbohydrate drinks and at high temperatures (30°C) was longer in 6% (112 mins) carbohydrate drink. In low temperatures, 4% and 6% Sugar-Based drinks improve exercise capacity and at high temperatures, 6% Sugar-Based drinks improve exercise capacity compared to placebo.</td>
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<td>11</td>
<td>Kamijo Y et al. (2012)</td>
<td>Japan</td>
<td>7 healthy males aged 19-31 years</td>
<td>1. High-carbohydrate (3.4 g glucose + 3.1 g fructose) electrolyte 2. Low-carbohydrate (1.7 g glucose + 1.6 g fructose) electrolyte 3. Control (no sugar)</td>
<td>In the high carbohydrate-electrolyte drink, plasma volume increased faster and remained at a high level, accumulate urine volume was smallest, renal Na+ absorption rate was greatest and plasma glucose and serum insulin were highest (p &lt; 0.05), compared to control. Sugar-Based electrolyte drinks have enhanced renal Na+ reabsorption compared to no sugar drinks during recovery from exercise-induced dehydration.</td>
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</tbody>
</table>
12 Clapp AJ et al. (2000) USA 18 healthy males aged 19-32 years 1. Lime coloured water 2. Lemon-lime placebo 3. Lemon-lime carbohydrate-electrolyte (18 mEq/L sodium with 6% carbohydrate) 4. Lemon-lime carbohydrate-electrolyte (36 mEq/L with 6% carbohydrate) As an indicator of hydration status, mean fluid consumption was significantly greater (771 mL per hr & 740.4 mL per hr) and weight loss much lower (-0.01% and +0.11%) for the carbohydrate drinks as compared to water and placebo Sugar-Based (6%) drinks produce better hydration than water for workers in industrial environment

Clinical Controlled Trial (CCT)

1 Ryan AJ et al. (1991) USA 9 healthy males aged 19-40 years 1. Non-carbonated Carbohydrate (6%) 2. Carbonated Carbohydrate (6%) 3. Non-carbonated Carbohydrate (10%) 4. Carbonated Carbohydrate (10%) For all beverages, gastric residual volumes (p > 0.05), ad libitum drinking (p < 0.05), sweat rate, % of body weight lost and % of fluid replaced by ad libitum drinking were similar Sugar- based (6% and 10%) carbonated drinks have the same influence on at-will drinking and gastric emptying as the Sugar-Based (6% and 10%) non-carbonated drinks during prolonged exercise

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<td>USA</td>
<td>8 healthy males aged 24-27 years</td>
<td>1-4. Glucose (2%, 4%, 6% &amp; 8%) 5-8. Sucrose (2%, 4%, 6% &amp; 8%) 9-12. Maltodextrin (2%, 4%, 6% &amp; 8%) 13-16. Corn Syrup solid (2%, 4%, 6% &amp; 8%) 17. Control</td>
<td>Water absorption was similar amongst all four 2%, 4% and 6% carbohydrate drinks and 8% sucrose and maltodextrin drinks (range: 9-15 ml/h/cm) and greater than the no-sugar control (3.0 ± 2.2 ml/h/cm; p &lt; 0.05).</td>
<td>Sugar-Based drinks with varying concentrations of upto 6% carbohydrate, exhibit similar effect on water absorption from intestines. However, increasing carbohydrate concentration 8% in glucose and corn syrup based sugar drinks reduces water absorption rate</td>
</tr>
</tbody>
</table>
2. Evans GH et al. (2009) UK 6 healthy males aged 21-31 years
   1. Glucose (2%)
   2. Glucose (10%)
   3. No-sugar
   The 2% and 10% carbohydrate drinks had more fluid retention (46 ± 9% and 40 ± 14%, respectively) compared to the no-sugar drink (27 ± 13%). 10% drink had longer euhydration than 2% drink

   1. No drink
   2. Carbohydrate (5g %) electrolyte – during exercise
   3. Carbohydrate (12.5g %) electrolyte – during recovery
   Improvements in total endurance time (51%), heart rate responses and blood lactate observed after delivery of 5g % drink and improvements in cardiovascular responses, blood glucose and lactate removal after delivery of 12.5g % drink
   Sugar-Based (5% and 12.5%) electrolyte drinks provide better performance endurance, enhance lactate removal and delay the onset of fatigue during exercise and recovery

Acknowledgement
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References
3. EFSA Panel on Dietetic Products, Nutrition and Allergies (NDA); Scientific Opinion on the substantiation of health claims related to water and maintenance of normal physical and cognitive function (ID 1102, 1209, 1294, 1331), maintenance of normal thermoregulation (ID 1208) and “basic requirement of all living things” (ID 1207) pursuant to Article 13(1) of Regulation (EC) No 1924/2006. EFSA Journal 2011; 9(4): 2075-16. Available online: www.efsa.europa.eu/efsajournal


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