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Osmolality and pH of sport and other drinks available in Switzerland

Abstract

Sports drinks are widely used during exercise to avoid or delay the depletion of the body's carbohydrate stores and the onset of dehydration. Both the osmolality and the pH of a sports drink can influence its effectiveness and its impact on mouth health. Unfortunately, data about osmolality and pH are usually missing on the labels of commercially available sports drinks and are unknown in the case of homemade sports drinks. Therefore, we analyzed the osmolality and pH of 35 sports and recovery drinks, as well as that of 53 other beverages usually consumed in Switzerland. The osmolality of the analyzed sports and recovery drinks varied over a relatively wide range (157–690 mmol/kg) with the homemade sports drinks being at the lower end and some commercial recovery drinks at the higher end. The osmolality of some commercial sports drinks, which are designed to be consumed during exercise, tended to be in the hypertonic range, although such drinks should rather be slightly hypotonic. The pH of nearly all analyzed sports drinks was in the range of about 3 to 4, which is of some concern because of the potential of low pH solutions to erode teeth. Although some of the tested sports drinks did not have an optimal osmolality, issues like individual tolerance and flavor preference of the drinks must also be considered before generally discouraging their consumption. Future generations of sports drinks should, however, also address the pH of the drinks to minimize their impact on dental erosion.

Zusammenfassung

Sportgetränke werden von Sportlern genutzt, um die Entleerung der körpereigenen Kohlenhydratreserven zu verhindern oder zu verzögern, und um einer Dehydratation entgegenzuwirken. Die Osmolalität und der pH von Sportgetränken können sowohl die Wirksamkeit wie auch die Zahngesundheit beeinflussen. Leider werden von den Herstellern meistens keine Angaben über Osmolalität und pH gemacht und im Falle von selbst hergestellten Sportgetränken sind die Daten ebenfalls unbekannt. Wir machten deshalb eine Marktübersicht über die Osmolalität und den pH von 35 kommerziell erhältlichen oder selbst hergestellten Sportgetränken sowie von 53 weiteren Getränken, die in der Schweiz konsumiert werden. Die Osmolalität der analysierten Sportgetränke variierte über einen relativ grossen Bereich von 157–690 mmol/kg, wobei die selbst gemachten Sportgetränke eher am unteren Ende und einige kommerzielle Regenerationsgetränke am oberen Ende der Skala zu finden waren. Die Osmolalität einiger Sportgetränke, die für den Konsum während der sportlichen Aktivität konzipiert sind, lag tendenziell im hypertonen Bereich, obwohl diese Getränke idealerweise eher leicht hypoton sein sollten. Der pH fast aller Sportgetränke war im Bereich von 3–4. Dies ist nicht ideal, da Getränke mit tiefen pH-Werten das Potenzial haben, den Zahnschmelz aufzuweichen. Obwohl einige Sportgetränke eine nicht ideale Osmolalität aufwiesen, sollten weitere Faktoren wie die individuelle Toleranz oder geschmackliche Präferenzen berücksichtigt werden, bevor man von einem Sportgetränk abrät. Zukünftige Generationen von Sportgetränken sollten jedoch die Problematik der tiefen pH-Werte angehen, um das zahnerodierende Potenzial zu reduzieren.

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Introduction

Sports performance can be impaired by many causes; two dominant factors leading to premature fatigue are the depletion of the body's carbohydrate stores and the onset of dehydration resulting from the loss of water and electrolytes in sweat [12]. Fatigue caused by energy depletion and/or dehydration can be postponed by the ingestion of sports drinks whose main purposes are to prevent dehydration, to supply energy, and to replace electrolytes [12]. Today, sports drinks are some of the best researched food items and there is a consensus about the optimal composition of such drinks: sports drinks should contain water, carbohydrates as an energy source, sodium for particular situations, and a defined osmolality [2, 4].

The osmolality of a beverage can influence the rate of gastric emptying and intestinal water flux [12, 20]. Hypotonic solutions promote gastric emptying and water absorption from the proximal

small intestine [10, 12, 13], whereas hypertonic solutions slow gastric emptying and fluid absorption, and probably also promote the occurrence of exercise-related abdominal pain (also called a stitch; [10, 15]). It is also reported that the perceived pleasantness of fluids increases with decreasing osmolality [1], a circumstance that may promote voluntary drinking.

Athletes consume sports drinks on a daily basis and the ingested amount can easily reach more than 1 L per day. Since sports drinks are usually ingested a sip at a time, the drinks' residue remains in the oral cavity for quite some time. This can influence tooth health because beverages such as sports drinks may have a low pH value, which in turn is related to dental erosion [14]. Indeed, different studies have revealed the potential of commercial sports drinks to erode teeth [3, 8, 14, 19].

While information on the carbohydrate type and content are normally displayed on the food package label of sports drinks, data on osmolality and pH are usually missing. As an alternative

to commercially available sports drinks, recommendations about the production of homemade sports drinks are in circulation and, at least in Switzerland, many athletes mix their own sports drinks using a selection of basic ingredients including water, sugar, fructose, glucose, maltodextrin, and syrup or fruit juices. Theoretically, the osmolality of such homemade drinks could be calculated as long as the exact amount of all ingredients is known. However, as soon as natural products like syrup, fruit juices or carbohydrates of undefined chain length like maltodextrin are used, the calculation of the osmolality becomes difficult.

To close the knowledge gap on the osmolality and pH data of sports drinks, we conducted a study to analyze both the osmolality and pH of many commercially available and homemade sports drinks. For comparison, we also analyzed a selection of other beverages commonly consumed in Switzerland.

Methods

Thirty-five commercially available and homemade sports drinks, 8 mineral waters, 19 soft drinks, 17 fruit juices or fruit drinks, and 9 alcoholic beverages were purchased in local shops in the Zurich area or obtained from local distributors in November 2005. The carbohydrate content of a beverage was taken from the food label; osmolality and pH were analyzed in our laboratory. The ingredients used to prepare the homemade sports drinks are given in the results section of this paper.

All beverages were analyzed a couple of days after purchase and always before the expiry date. Before analysis, sparkling beverages were shaken until no gas bubbles were seen in the beverages, and beverages sold as powder were prepared according to the manufacturer instructions using a precision laboratory scale (Mettler PM 3000, Nänikon-Uster, ZH, Switzerland) and deionized water as a solvent (the difference from tap water is about 3 mmol/kg).

Osmolality was measured by freezing point depression (Osmometer 2020, Advanced Instruments, Norwood, MA, USA) and pH with a pH meter (Model 632, Metrohm, Herisau, AI, Switzerland). Both analyzers were calibrated according to the manufacturer's instructions before measurements were taken. Measurements of osmolality were done in duplicate and only the mean values are presented. The mean coefficient of variation for the duplicate measurements was 0.009.

Results

The carbohydrate content, the osmolality and the pH of the different sports drinks are presented in *Table 1* and data of other beverages are given in *Table 2* in alphabetic order.

Discussion

The osmolality of the analyzed sports drinks varied over a relatively wide range with the homemade drinks being at the lower end (*Table 1*). In general, osmolality increases with increasing total carbohydrate content, but it is also strongly influenced by the proportion of monosaccharides, disaccharides or polysaccharides. Therefore, osmolality does not directly depend on the carbohydrate content. Ethanol is another substance that strongly increases osmolality (see alcoholic beverages in *Table 2*). Actually, the assessment of sports drinks is multifaceted. The parameters of gastric emptying and intestinal absorption, for example, are influenced by different factors like the volume of fluid, energy density, exercise intensity, mental stress or osmolality [2, 12, 13]. However, in the following we will focus on osmolality.

The idea behind using the term isotonic in the context of beverages is to communicate that a beverage contains the same number of osmotic active substances per unit of mass as blood, whose osmolality is normally regulated around 280–290 mmol/kg [17]. According to the Swiss government decree on speciality food [5]

	Physical state at purchase	Carbohydrate [g/100 g]	Osmolality [mmol/kg]	pH
Commercially available sports drinks				
Gatorade Mandarine	Liquid	6.0	348	3.3
Gatorade Green Apple	Liquid	6.0	362	3.2
Gatorade Red Orange	Liquid	6.0	350	3.2
Gatorade Arctic Snow	Liquid	6.0	353	3.4
Gatorade Orange	Powder	6.0	297	3.0
Gatorade Citron	Powder	6.0	297	3.1
Isostar Fast Hydration	Liquid	6.7	301	3.9
Isostar Hydrate+				
Perform Citron	Liquid	6.7	322	3.8
Isostar Hydrate+Perform	Powder	7.0	271	3.8
Isostar Long Energy	Powder	15.1	260	3.4
M-Isodrink	Powder	8.2	289	3.0
PowerBar PowerGel				
(diluted 1:4)	Gel	12.8	340	3.7
PowerBar Performance				
Sports Drink Orange	Liquid	4.9	302	3.7
PowerBar Performance				
Sports Drink Orange	Powder	6.6	295	3.8
Powerade Mountain Blast	Liquid	8.2	391	3.5
Powerade Orange	Liquid	8.2	346	3.5
Rivi Marathon	Powder	5.0	210	3.2
Sponser Hypotonic	Powder	5.0	238	3.5
Sponser Isotonic				
Red orange	Powder	7.0	312	3.1
Sponser Liquid Energy				
(diluted 1:4)	Gel	15.0	533	6.2
Sportvital Energy				
Formula	Powder	4.1	214	4.4
Sportvital Quick				
Energy Gel (diluted 1:4)	Gel	12.0	291	3.9
Verofit Isotonic Tropical	Powder	5.2	263	3.4
Vittel Action	Liquid	5.5	294	4.0
Home-made sports drinks				
Drink 1: Peppermint tea 1 L				
Sucrose 30 g, Maltodextrin* 50 g,				
NaCl 1.5 g		7.8	184	6.9
Drink 2: Peppermint tea 1 L				
Fructose 30 g, Maltodextrin* 50 g,				
NaCl 1.5 g		7.8	264	7.1
Drink 3: Tap water 1 L				
Syrup raspberry 30 g,				
Maltodextrin* 50 g, NaCl 1.5 g		7.3	157	3.4
Drink 4: Tap water 1 L				
Syrup raspberry 30 g,				
Maltodextrin* 90 g, NaCl 1.5 g		11.1	186	3.4
Drink 5: Tap water 1 L				
Sucrose 15 g, Fructose 15 g,				
Maltodextrin* 50 g, NaCl 1.5 g		7.8	215	6.3
Commercially available recovery drinks				
Isostar Recovery	Powder	13.9	508	6.5
PowerBar Proteinplus				
Recovery Drink				
Chocolate	Powder	18.0	657	6.4
Sponser Recovery Drink	Powder	15.7	690	4.2
Sponser Regeneration				
Competition	Liquid	15.0	427	3.8
Sportvital Regeneration				
Quadra Pro	Powder	9.1	373	6.1
Verofit Recovery				
Chocolate	Powder	16.0	600	6.6

* For all home-made drinks Maltodextrin 100 (Sponser Sport Food, Wollerau, Switzerland) was used.

Table 1: Carbohydrate content, osmolality and pH of sports drinks available in Switzerland in alphabetical order. All data refer to the ready-to-drink beverage.

	Carbohydrate [g/100 g]	Osmolality [mmol/kg]	pH
Mineral waters			
Adelbodner	0	32	5.7
Contrex (mineralization: 2174 mg/L)	0	27	7.1
Eptinger (2630 mg/L)	0	33	5.8
Henniez (581 mg/L)	0	18	5.9
Rhätzünser (1643 mg/L)	0	39	6.3
Tap water (Zürich)	0	3	7.4
Valser (1918 mg/L)	0	27	6.1
Valser Viva Limette	0	39	5.7
Fruit drinks			
Apple juice clear <i>Juice Migros</i>	11	736	3.3
Apple juice clear <i>Juice Migros</i> (diluted 1:1)	5.5	343	3.3
Apple juice clear <i>Juice Migros</i> (diluted 1:3)	2.8	171	3.4
Apple juice clear <i>Juice Migros</i> (diluted 1:7)	1.4	82	3.5
Apple juice unfiltered <i>Juice Migros</i>	11	727	3.3
Bodyguard Michel	11	675	3.4
Carrot juice Biotta	9	561	4.2
Fruit cocktail Hawaii <i>Gold Migros</i>	12	717	3.7
Grape juice <i>Gold Migros</i>	16	1193	3.3
Grapefruit juice <i>Juice Migros</i>	11	610	3.2
Multivitamin <i>Gold Migros</i>	12	779	3.5
Orange juice <i>Juice Migros</i>	12	614	3.6
Orange juice with pulp Granini	9	621	3.6
Orange juice with pulp Michel	11	594	3.8
Orange juice with pulp Michel (diluted 1:1)	5.5	282	4.0
Orange juice with pulp Michel (diluted 1:3)	2.8	139	4.0
Orange juice with pulp Michel (diluted 1:7)	1.4	71	4.0
Pear juice <i>Juice Migros</i>	11	733	3.7
Pineapple juice <i>Gold Migros</i>	13	692	3.8
Pineapple juice <i>Gold Migros</i> (diluted 1:1)	6.5	309	3.9
Pineapple juice <i>Gold Migros</i> (diluted 1:3)	3.3	158	3.9
Pineapple juice <i>Gold Migros</i> (diluted 1:7)	1.6	77	3.9
Shorley (60% Apple juice) Möhl	6	410	3.7
Tomato juice Naturaplan Bio Coop	3	475	4.1
Vitafit Coop	14	777	3.4
Soft drinks			
Coca Cola	10.6	493	2.4
Coca Cola light	0	27	2.5
Fanta	10.1	415	2.6
Lipton Ice Tea Lemon*	8.0	268	3.1
Lipton Ice Tea Light	0	29	3.4
Nestea Lemon	7.6	278	3.6
Nestea Light	0	46	3.5
Pepsi light	0.5	25	2.7
Pepsi max	0.5	27	2.8
Red Bull	11.3	601	3.3
Red Bull Sugarfree	0	140	3.2
Rivella blau	1.5	120	3.2
Rivella rot	9	425	3.4
Schweppes Bitter Lemon	12	627	2.7
Schweppes Ginger Ale	NA	497	2.7
Schweppes Tonic	8.9	501	2.5
Syrup raspberry Coop (diluted 1:4)	17	756	3.2
Sprite	10.1	479	2.7
Alcoholic beverages			
Bacardi Breezer Orange	NA	1050	2.6
Cider Ramsauer	3	1159	3.5
Clausthaler beer non alcoholic	NA	275	4.3
Clausthaler Panaché non alcoholic	NA	452	3.0
Desperados Tequila	NA	1379	3.2
Dr. Pepper	10	646	2.6
Eichhof beer alcoholic	3.5	1047	4.1
Red wine	NA	2573	3.4
Smirnoff Ice New Taste	NA	1192	3.2

NA = Data not available from the food label

* Product has changed in the meantime to lower carbohydrate content.

Table 2: Carbohydrate content, osmolality and pH of mineral waters, fruit drinks, soft drinks, and alcoholic beverages in alphabetical order.

a beverage for persons with increased energy and nutrient needs can be declared as «isotonic» when its osmolality is in the range of 250–340 mmol/L¹. This leads to two problems. First, this legal use of the term «isotonic» for sports drinks with an osmolality of up to 340 mmol/L is misleading, because osmolalities above 290 mmol/kg already promote initial water secretion into the intestinal lumen [11]. Second and contrary to widespread belief, even the really isotonic beverages (around 280 and 290 mmol/kg) are not the ones that are absorbed the fastest. This fact should already become evident when considering that per definition there is a water flux from hypotonic solutions in direction to the hypertonic counterpart and along the osmotic gradient. In the case of beverages, this means that water from hypotonic beverages is pulled into the circulation, which represents the hypertonic compartment. This pulling force is, by definition, not present when two solutions are isotonic to each other. Indeed, it is suggested that intestinal water absorption rates are higher with hypotonic solutions compared with isotonic solutions [10, 13]. The optimal osmolality for a sports drink has, therefore, been defined to be in the slightly hypotonic range between 200 and 250 mmol/L [13].

As there is evidence that not only fluid absorption, but also palatability and intestinal tolerance tend to be better with hypotonic beverages [1, 12, 13, 15], it is surprising that some commercial sports drinks were rather high in the hypertonic range. Some sports drinks had osmolalities of more than 350 mmol/kg. If a sports drink is to be consumed during exercise, when the risk of gastrointestinal discomfort is higher than at rest, an osmolality in the range of 200–250 mmol/kg would be more suitable. On the other hand, a hypertonic drink usually does not cause discomfort when ingested at rest, such as during the recovery phase of an exercise bout. The high osmolality of sports recovery drinks is, therefore, not an issue of concern – as long as fast rehydration is not the primary goal. Otherwise the problem may easily be solved by increasing the dilution of the beverage.

Since we found not only hypertonic sports drinks, but also some sports drinks with a rather low osmolality (in particular among the homemade sports drinks), the question might arise if an osmolality lower than the one suggested for optimal sports drinks (200–250 mmol/kg) is of concern. According to a study by Gisolfi et al. [6] the observed water absorption rates of sports drinks with an osmolality of 169 mmol/kg and 245 mmol/kg were not different and the amount of glucose required to stimulate water absorption is supposed to be relatively small [10].

A more practical question arises with sports drinks that are sold as powders. Depending on how precisely the amount of the powder can be weighed, the concentration and thus the osmolality of the beverages can vary. Most manufacturers solve this issue with a dosage spoon or by using portion bags. In most cases, it was sufficient to follow the manufacturer's instruction to achieve an osmolality that varied only a little, irrespective of whether the dosage spoon was filled very carefully or in a hasty real-life shoveling way (data not shown). However, a relevant problem was detected with one manufacturer (Gatorade) where the powder had to be measured by filling a pretty wide cap with a dosage line that was not easily visible. This system was not practical and it was easy to substantially overdose the beverage and consequently produce a hypertonic sports drink. We would suggest reconsidering the use of this dosage system.

An unexpected result of this study was the consistently low pH of nearly all commercially available sports drinks as well as of the homemade drinks based on syrup. The only sports drinks with a neutral pH were the homemade drinks based on water or tea and with added carbohydrates as an energy source. Different studies detected the potential of commercial sports drinks to erode teeth [3, 8, 14, 19]. Although ways to significantly influence the pH and erosive potential of sports drinks exist [3, 7, 9], this aspect does not

¹ To calculate osmolality (mmol/kg) from osmolality (mmol/L), the density of a fluid must be known. Provided that carbohydrates are the predominant osmotic substance like in sports drinks but not in blood, setting osmolality equal to osmolality would lead to an underestimation of osmolality by only about 1% per 30 g carbohydrates per liter.

seem to be of relevance for the manufacturers at this time. However, the pH value of a sports drink could easily become a marketing issue with potentially beneficial or detrimental consequences for the manufacturers. Besides the pH, other factors like the titratable acid (not measured in this study) are also determinants of the erosive potential [3].

The attentive reader recognizes that dilutions of some fruit juices do not show an absolute linear behavior with the osmolality. This can be seen especially between the pure juice and the 1:1 dilution with water, while the further dilutions come along with a very similar linear reduction of the osmolality. This is an artifact of the freezing point depression method [18] as the fruit juices do not behave like an ideal solution over the whole concentration range. However, the discrepancy is not very large and the measuring error is practically not relevant.

Closing Remarks

Sports drinks are an indispensable tool to achieve a sufficient daily carbohydrate intake and to postpone fatigue during exercise and competition in many elite sports. Although some of the tested sports drinks did not have an optimal osmolality, this is not yet a sufficient reason to generally discourage their consumption, if one likes such sports drinks. An important issue not discussed so far, is the individual tolerance and flavor preference of a drink as this influences voluntary fluid intake and gastrointestinal comfort [12, 13, 16]. In contrast, a matter of real concern is the potential for dental erosion related to the low pH value of many tested sports drinks. Future generations of sports drinks should address this issue.

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