Osmolality, pH, and titratable acidity of sports drinks on the Swiss market

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Abstract

The regular consumption of acidic drinks can erode dental enamel and promote caries. As many sports drinks on the market feature critically low pH values, it is possible that athletes with regular sports drink consumption harm their oral health. As neither pH nor osmolality values must be labeled on products, it is difficult for athletes to make informed choices.

We screened the Swiss market for sports drinks and gels for domestic and international brands and products and analyzed products for their pH, titratable acidity, and osmolality.

For all analyzed parameters, the results varied widely. We identified several products with a neutral pH and or low titratable acidity. On the other hand, there are still many products on the market with a critically low pH and significant titratable acid content. Acidity was not only variable between different products, but also between different flavors of the same product. Osmolality also featured significant variability, with some products showing dedicated hypotonic osmolality and a few products exceeding 300 mosmol/kg. Overall, osmolality values have clearly dropped since our last market screening in 2006.

Today, athletes can choose from a variety of products with low acidity and optimized osmolality. Athletes who prefer drinks with a high dental erosive potential should consider a special focus on dental hygiene and health.

Keywords:
Sports nutrition, gel, carbohydrates, oral health, dental erosion, caries

Zusammenfassung

Der Konsum von säurehaltigen Getränken kann zu erosiven Schäden am Zahnschmelz beitragen. Weil viele kommerzielle Sportgetränke einen für den Zahnschmelz kritischen pH-Wert aufweisen, kann sich ein regelmässiger Konsum entsprechend auf die Zahngesundheit auswirken. Da weder der pH noch die Osmolalität deklariert werden müssen, ist es schwierig, diese Parameter bei der Produktauswahl zu berücksichtigen.

Wir haben Sportgetränke und Gels von nationalen und internationalen Markenherstellern auf dem Schweizer Markt auf pH, titrierbare Säure und Osmolalität analysiert.

Für alle analysierten Parameter wurde eine starke Streuung festgestellt. Einige Produkte wiesen einen neutralen pH-Wert und/oder eine tiefe titrierbare Säure auf. Andererseits wiesen viele Produkte kritisch tiefe pH- und hohe Säurewerte auf. Die titrierbare Säure hat sich nicht nur zwischen verschiedenen Produkten, sondern auch zwischen verschiedenen Geschmacksrichtungen desselben Produkts unterschieden. Bei der Osmolalität wiesen verschiedene Produkte deutlich hypotonische Werte auf, während andererseits einige Produkte 300 mosmol/kg überschritten. Seit 2006 sind die Osmolalitätswerte auf breiter Front reduziert worden.

Heute haben Sportlerinnen und Sportler mehrere bzgl. Osmolalität und Säuregehalt optimierte Produkte zur Auswahl. Wer Getränke mit erhöhtem erosivem Potenzial bevorzugt, sollte die Zahnhygiene entsprechend beachten.

Schlüsselwörter:
Sporternährung, Gels, Kohlenhydrate, Zahngesundheit, Zahnerosion, Karies

Introduction

Over the last three decades, a significant body of literature has documented the ergogenic effects of exogenous carbohydrates and the delivery of fluid during longer exercise activities [1]. Since the invention of Gatorade, commercial as well as self-made sports drinks have become staple products in the field of sports nutrition to deliver carbohydrates and fluid during exercise.

Of course, it is advisable to use these products to demand only. The excessive consumption of sugary drinks is not warranted for the general population as well as for athletes. However, even the meaningful consumption of sports drinks may have its side effects. One potential problem associated with the regular consumption of sports drink is their erosive effect on dental enamel. Dental erosion is tooth structure loss resulting from acid challenge to the enamel surface [2]. Poor oral health is a significant and often neglected issue in sports, which may also negatively affect performance [3-7]. Several aspects from individual oral hygiene to nutritional behavior all contribute to the oral health outcome. Regular exposure of the teeth to acidic drinks may contribute to tooth decay over the years or over an athletic career [2], particularly as the erosive potential of some commercial sports drinks has been shown to be worse than with Coca Cola [8].

The erosive potential of drinks is significantly determined by the pH of the liquid and the concentration of the acid [2,9]. However, information on the pH and acid concentration do not have to be labeled, and most manufacturers do not publish this information. Consequently, it is difficult for athletes to consider the pH or acid concentration of the consumed drinks. A screening on the Swiss market in 2006 revealed that basically all commercially available sports drinks, including domestic and international brands, featured critically low pH values regarding dental erosion. Since then, some new products with dedicatedly pH-neutral properties have entered the market.

Another characteristic of sports drinks that does not have to be labeled but with a certain practical relevance is the osmolality of the drink. Osmolality may influence gastric emptying rates and residual intragastric fluid volumes [10,11]. Although carbohydrate content is clearly dominant regarding gastric emptying and fluid absorption, osmolality also plays a role [12]. While the carbohydrate content is labeled or can easily be calculated by the consumer, there is usually no labeled information on the osmolality of the drink. For optimal fluid absorption, ingested fluids during exercise should be isotonic to hypotonic in relation to human plasma [12,13]. Our market screening in 2006 revealed that several commercial sports drinks showed osmolality values significantly beyond 300 mosmol/kg, with several internationally marketed products showing values between 346 and 391 mosmol/kg [14]. There is evidence that these higher values approach dimensions where gastric emptying and fluid absorption is significantly reduced [10]. Over the last decade, several products with dedicatedly lowered osmolality ("hypotonic" sports drinks) have been launched, and several product recipes have been updated by the manufacturers. However, how these product updates translated into changed chemical properties is unknown.

Therefore, we intended to make a new market screening to consider newly introduced products and updated product recipes. The goal was to measure the osmolality, pH, and titratable acidity of domestic and international brands available on the Swiss market. These data should help athletes and dietitians in making informed choices.

Methods

In this investigation, we searched for liquid products designed to deliver carbohydrates during exercise for athletes, i.e., sports drinks and gels.

From October 2016 through January 2017, products on the Swiss market were screened through internet searches on retailer platforms as well as identified websites of manufacturers. Further, local retail stores and fitness centers were screened for offered products. For some selected products, we analyzed several available flavors to identify differences in the pH, acidity, or osmolality between different flavors of the same product. It was beyond the capability of this study to purchase and analyze all available flavors of all products on the market. Some of the products were provided by manufacturers via e-mail request. If products were not provided, they were purchased from local retail stores or from the internet.

For comparison reasons and because athletes occasionally use them during exercise, we included a few selected soft- and energy drinks in the study. In the case of carbonated beverages, we measured the product as it came from the shelf and after removing the carbon dioxide by intensive shaking until no gas bubbles could be identified in the beverage.

Liquid beverages were directly analyzed. Powders, tabs, or concentrated liquids were mixed with deionized water as a solvent (the osmolality difference from local tap water was 3 mosmol/kg) and according to the manufacturer's instructions (g of powder and ml of solvent). In some cases, alternative concentrations have been produced as indicated. Gels were analyzed in two ways. First, they were diluted with the amount of water suggested by the manufacturer. If no particular liquid volume was suggested by the manufacturer, a volume of a comparable product was chosen, as indicated in the results. Second, we diluted the amount of gels containing 20 g of carbohydrates with 200 ml of deionized water to get a carbohydrate-matched comparison between products. Unfortunately, not all gels could be analyzed in both ways. The gels of Winforce have a relatively unique texture and contain significant amounts of fat. It was not possible to properly solve and analyze this product with the same methodology.

Osmolality was measured by the freezing point depression (Osmopro 3250, YASN, England). Titratable acidity was measured by titrating 200 ml of a sample to a pH of 7.0 with 1 mol NaOH using a digital semiautomatic burette (TitrasPro 613-5287, VWR Collection, Deutschland). The pH was measured with a digital pH meter (SevenCompact S210, Mettler Toledo, Schweiz). To weigh the products and ingredients, a precision scale was used (LPWG-723i, VWR Collection, Italy). Products were weighed to the nearest 0.01 g. All measuring devices were calibrated according to the manufacturer's instructions. For volume measurements, calibrated volumetric flasks were used. The powder products were prepared and analyzed in duplicate (pH, acidity) to minimize the errors of preparing the products and to check measurement precision. The average standard error of these repetitive measures was <0.01 ± 0.01 / 0.01 (mean ± standard deviation / median) for the osmolality and pH and 0.05 ± 0.05 / 0.04 for acidity. The precision of the acidity titration was reduced for drinks with a pH close to 7.0, resulting in an increased signal-to-noise ratio. The results are presented as mean values.

Results

The osmolality for sports drinks varied between 100 and >300 mosmol/kg, depending on the concentration of the product. Titratable acidity varied massively from zero up to 85.8 mmol NaOH per liter of sports drink. The osmolality, pH, and titratable acidity of the analyzed sports drinks as well as some selected other beverages are shown in Tables 1 and 2, respectively. The resulting values for gels consumed with the manufacturer's or estimated amount of water as well as the 20 g carbohydrate matched dilutions are listed in Tables 3 and 4, respectively.

Product	Purchased form	pH	mmol NaOH to pH 7 / liter	Osmolality [mosmol/kg]	CHO/100 ml[1]
Dextro Energy, Isotonic Sports Drink, Orange Flavor	Powder	4.2	49.5	284	7.0
Gatorade, Citrus Mix Flavor	Ready to drink	3.4	30.1	246	4.1
Gatorade, Cool Blue	Ready to drink	3.2	47.1	218	5.8
Gatorade, Lemon Flavor	Powder	3.2	48.3	288	6.0
Gatorade, Orange Flavor	Powder	3.2	43.5	301	6.0
Gatorade, Red Orange	Ready to drink	3.2	47.9	285	5.9
Gatorade, Mandarine Flavor	Ready to drink	3.3	44.6	273	5.9
High5, Energy Source, Citrus Flavor	Powder	4.0	28.8	277	8.8
High5, Energy Source, Orange Flavor	Powder	4.0	28.2	274	8.8
High5, Energy Source, Summer Fruits Flavor	Powder	3.9	29.6	313	8.8
High5, Energy Source, Tropical Flavor	Powder	3.8	32.4	276	8.8
Isostar, Fast-Hydration, Fresh	Ready to drink	3.9	57.6	319	6.7
Isostar, Fast-Hydration, Lemon	Ready to drink	3.9	41.6	306	6.9
Isostar, Fast-Hydration, Orange	Ready to drink	4.0	42.6	307	7.0
Isostar, Hydrate & Perform, Lemon	Powder	4.0	49.5	262	7.0
Isostar, Fast Hydration Powertabs, Orange	Tabs	4.0	78.2	289	3.8
Maurten, Drink Mix 160, Neutral	Powder	4.8	2.9	203	7.8
Multipower, Energy Charge, Orange Flavor	Ready to drink	3.2	48.0	663	14.0
Multipower, Energy Charge, Tropical Fruit Flavor	Ready to drink	3.2	48.4	645	14.0
Multipower, Iso Drink, Fresh Orange Flavor	Powder	3.7	22.8	309	6.2
Optidrink, Optimix, Peach	Powder	2.7	21.5	142	6.0
Optidrink, Saltix, Citron	Powder	8.1	0.0	315	7.0
Optidrink, SäurEx, Orange	Powder	8.1	0.0	216	
Powerade, Blood-Orange	Ready to drink	2.6	34.2	292	3.8
Powerade, Moutain-Blast	Ready to drink	2.6	34.7	285	3.9
Powerade, Orange	Ready to drink	2.6	35.1	281	3.9
PowerBar, Isoactive, Red Fruit Punch	Powder	3.8	37.1	333	5.8
PowerBar, Isolite, Grapefruit-Lemon	Ready to drink	2.7	85.8	307	4.3
PowerBar, Isomax, Blood Orange Flavor	Powder	4.1	22.7	305	5.9
PowerBar, L-Carnitine, Pineapple	Ready to drink	3.5	42.3	128	1.6
Rivi Marathon, Fruit Mix	Powder	3.6	30.2	133	4.6
Sponser, Carbo Loader, Citrus-Orange	Powder	4.1	20.2	346	18.3
Sponser, Competition, Citrus	Powder	6.2	2.5	226	7.7
Sponser, Competition, Fruit Mix	Powder	6.1	2.2	232	7.7
Sponser, Competition Ultra, Neutral	Powder	6.2	2.3	100	7.8

Table 1: pH, titratable acidity, osmolality and carbohydrate content of sports drinks (Continued on the next page)

Product	Purchased form	pH	mmol NaOH to pH 7 / liter	Osmolality [mosmol/kg]	CHO/100 ml[1]
Sponser, Competition, Orange, hypotonic [2]	Powder	6.2	2.0	266	7.7
Sponser, Competition, Orange, isotonic [3]	Powder	6.2	2.4	406	11.6
Sponser, Competition, Raspberry	Powder	6.2	3.2	230	7.7
Sponser, Energy Sport Tea Getränkekonzentrat, Icetea-Peach	Concentrated liquid	3.2	18.0	252	3.9
Sponser, Isotonic, Citrus	Powder	4.0	26.8	338	7.0
Sponser, Isotonic, Fruit Mix	Powder	3.6	45.9	300	6.9
Sponser, Isotonic, Peach	Powder	3.7	36.0	329	7.0
Sponser, Isotonic, Red Orange	Powder	3.5	52.4	307	7.0
Sponser, Long Energy, Berry	Powder	5.9	7.7	242	6.3
Sponser, Long Energy, Citrus	Powder	5.8	5.8	231	7.0
Sponser, Long Energy, Fruit Mix	Powder	5.8	5.0	233	7.0
Sponser, Ultra Pro, Coconut	Powder	5.9	25.1	406	17.6
Verofit, GOLD, Lemon	Powder	3.5	30.4	236	8.5
Verofit, GOLD, Orange	Powder	3.6	26.7	245	8.5
Verofit, Isotonic, Blutorange	Powder	3.2	61.3	276	7.7
Verofit, Isotonic, Citrus	Powder	3.0	75.8	277	7.7
Verofit, Isotonic, Exotic	Powder	3.7	33.6	294	7.7
Verofit, Isotonic, Tropical	Powder	3.6	37.2	281	7.7
Winforce, Carbo Basic Plus, Neutral	Powder	6.4	0.5	175	7.6
Winforce, Carbo Basic Plus, Pfirsich	Powder	6.2	0.7	177	7.6
Winforce, Carbo Basic Plus, Zitrone	Powder	3.4	19.5	184	7.6
Winforce, Isotonisches Sportgetränkekonzentrat, Granatapfel	Concentrated liquid	3.2	25.6	206	4.4
Raspberry (70 g raspberry syrup Migros + 930 g water + 20 g maltodextrin + 1.5 g NaCl)	self-made	3.1	10.9	253	
Tea (1000 ml herbal tea + 30 g sugar + 50 g maltodextrin + 1.5 g NaCl)	self-made	7.3	0.0	179	
Tea (1000 ml herbal tea + 30 g fructose + 50 g maltodextrin + 1.5 g NaCl)	self-made	7.4	0.0	260	
Diluted Juice (500 ml orange juice + 500 ml water)	self-made	3.9	55.2	258	
Diluted Juice (500 ml orange juice + 500 ml water + 1.5 g NaCl)	self-made	3.8	54.9	302	
Diluted Juice (500 ml apple juice + 500 ml water)	self-made	3.3	41.4	295	
Diluted Juice (500 ml apple juice + 500 ml water + 1.5 g NaCl)	self-made	3.3	41.1	336	
Diluted Juice (500 ml cranberry juice + 500 ml water)	self-made	2.8	45.0	155	
Diluted Juice (500 ml cranberry juice + 500 ml water + 1.5 g NaCl)	self-made	2.8	45.6	199	

[1] Labeled product information, not analyzed
[2] standard dilution as indicated by the manufacturer (i.e. 60 g powder with 750 ml)
[3] increased concentration as indicated by the manufacturer (i.e. 60 g powder with 500 ml)

Product	product	pH	mmol NaOH to pH 7 / liter	Osmolality [mosmol/kg]	CHO/100 ml
Adelholzener, Active O2, Apple-Kiwi	Soft drink	3.1	27.8	227	3.7
Aproz, Raspberry-lime	Soft drink	3.9	45.7	186	4.0
Coca Cola (carbonated as purchased)	Soft drink	2.5	63.2	449	10.6
Cola Cola (decarbonated)	Soft drink	2.5	36.3	477	10.6
Denner, Ice Tea, Peach	Soft drink	3.0	34.4	433	8.0
Go Coco, Coconut Water	Soft drink	5.4	5.1	392	5.2
Nestea, IceTea, Lemon	Soft drink	3.4	29.5	184	4.6
Rivella rot (decarbonated)	Soft drink	3.3	59.9	387	9.0
Rivella rot (carbonated as purchased)	Soft drink	3.3	75.2	433	9.0
Migros, Syrup, raspberry, diluted 1:6 syrup: water (volume)	Syrup	3.0	21.2	346	
Monster, Energy (decarbonated)	Energy drink	3.5	105.4	683	11.0
Red Bull (decarbonated)	Energy drink	3.4	100.0	649	11.0
Coop, Qualité & Prix, Apfelsaft klar	Fruit juice	3.3	76.4	709	11.0
Granini, Orangensaft ohne Fruchtfleisch	Fruit juice	3.8	110.6	592	9.0
Michel, Cranberry, fruit juice	Fruit juice	2.8	88.8	315	7.0
Ramseier, Schorle	Fruit juice	3.3	80.6	407	6.2
Emmi, Comella, chocolate	Milk drink	6.8	26.8	500	10.0
Aproz, Cristal	Mineral water	7.5	0.0	22	0.0
Evian	Mineral water	7.3	0.0	6	0.0
Swiss Alpina	Mineral water	7.4	0.0	14	0.0
Valser, Silence	Mineral water	7.9	0.0	6	0.0

Table 2: pH, titratable acidity, osmolality and carbohydrate content of some selected energy- and soft drinks and other drinks.

Product	water [ml]	pH	mmol NaOH to pH 7	Osmolality [mosmol/kg]
Clif, Shot Energy Gel, Himbeere	150	3.83	19.0	392
Isostar, Energy Gel, Cherry	150	2.90	11.0	555
Isostar, Energy Gel, Strawberry-Banana	150	2.88	15.9	572
Isostar, Fruit Gel Energy, Exotic Flavour	400	3.93	14.5	168
PowerGel, Hydro, Cherry	150	3.77	52.6	580
PowerGel, Hydro, Orange	150	3.78	59.5	555
PowerGel, Original, Green Apple	150	4.51	16.3	578
PowerGel, Original, Strawberry-Banana	150	3.95	6.1	466
Sponser, Liquid Energy BCAA, Strawberry-Banana	400	4.92	13.1	335
Sponser, Liquid Energy Plus, Neutral	400	5.41	9.9	356
Sponser, Liquid Energy, Neutral	400	6.37	2.2	374
Sponser, Liquid Energy, salty	200	6.56	4.1	268
Verofit, Energy Gel 2+1, Neutral	200	6.30	3.2	300
Vitargo, Lemon	200	3.39	1.9	453
Winforce, Ultra Energy Complex, Banane *				
Winforce, Ultra Energy Complex, Haselnuss *				
Winforce, Ultra Energy Complex, Kokosnuss *				
* product was not sufficiently water soluble for analysis				

Table 3: pH, titratable acidity, osmolality and carbohydrate content of carbohydrate gels, diluted with the suggested fluid volume of the manufacturer or an estimated fluid volume.

Product	g Gel for 20 g CHO	Water	pH	mmol NaOH to pH 7	Osmolality [mosmol/kg]
Clif, Shot Energy Gel, Himbeere	28.2	200 ml	3.01	14	259
Isostar, Energy Gel, Cherry	25.6	200 ml	3.07	7	317
Isostar, Energy Gel, Strawberry-Banana	25.6	200 ml	3.03	7	318
Isostar, Fruit Gel Energy, Exotic Flavour	40.0	200 ml	3.99	11	174
PowerGel, Fruit Red, Fruit Punch	32.3	200 ml	4.34	12	354
PowerGel, Original, Green Apple	30.8	200 ml	4.55	8	331
PowerGel, Original, Strawberry-Banana	32.3	200 ml	4.17	2	302
Sponser, Liquid Energy BCAA, Strawberry-Banana	37.0	200 ml	4.91	13	376
Sponser, Liquid Energy Plus, Neutral	28.2	200 ml	5.43	8	320
Sponser, Liquid Energy, Neutral	28.2	200 ml	6.36	1	313
Verofit, Energy Gel 2+1, Neutral	32.8	200 ml	6.31	0	253

Table 4: pH, titratable acidity, osmolality and carbohydrate content of carbohydrate gels. The amount of gel for 20 g carbohydrates was diluted with 200 ml of water.

Discussion

The goal of this study was to obtain an overview of the osmolality, pH, and titratable acidity of sports drinks and carbohydrate gels on the Swiss market. The identified range for all these parameters was wide, which coincides with what we have observed in our 2006 screening [14].

pH and titratable acidity

Drinks with a pH of approximately 5.5 or below can erode dental enamel [3,8,15]. However, the amount of titratable acidity is considered the more important parameter regarding the erosive potential of a solution than the simple pH of the drink [8,16]. In 2006, all analyzed sports drinks showed critically low pH values of between 3 and 4, while acidity was not titrated [14]. In the present study, we found different sports drinks with uncritical pH values (i.e., > 5.5) and/or very low titratable acidity. Interestingly, the acidity varied significantly between different products and between different flavors of the same product. Acidity differences between flavors of the same products coincide with the instance that acidity is added primarily for taste reasons. Several manufacturers do not offer sports drinks with uncritical pH values and acidity regarding oral health. Of course, removing acidity has inevitable taste consequences. Acidity, taste, and food technology are beyond the scope of this article, but generally speaking, acid-free drinks have a distinctive milder taste than acidic drinks. Taste preferences and drink acidity also have to be considered at the individual level. Some manufacturers offer variants of their products without flavor and without acidity, e.g., Sponser (product: Competition), Winforce (Carbo basic), or Isostar (Hydrate & perform: not analyzed in this survey).

In addition to pH and titratable acidity, other parameters can influence the erosive potential, i.e., chemical factors (buffering capacity of the product, type of acidity, adhesion to the dental surface, chelating properties, calcium content), biological factors (saliva flow rate and composition, tooth composition), or behavioral factors like oral hygiene practices [17]. Different acids may have significantly different erosive potentials [9]. Further, the addition of calcium can strongly mitigate the erosive potential, particularly of citric acid [9]. Hence, it is not compelling to completely remove acidity to reduce or abolish the erosive potential. E.g., yogurt has a critical pH of approximately 4 but little to no erosive effect because of its high calcium and phosphor content [17]. A strong reduction of dental erosion has been shown with 300 to over 1000 mg calcium per liter of critically acidic drinks [15,18,19]. Consequently, the strategy of adding calcium may be limited in the case of sports drinks, as critically high calcium intakes might be induced when drinking larger volumes.

Of course, it is possible to consume acidic sports drinks. The acidity and osmolality of sports drinks are just two criteria among many others. The primary criterion should always be the individual taste preference and individual gastrointestinal tolerance. Nevertheless, athletes regularly consuming critically acidic sports drinks should be aware of the associated dental risks and try to maintain good oral health practices, e.g., including the regular application of fluoridated products to harden and recover the weakened enamel surface [2].

In addition to commercial sports drinks, it is also possible to consume self-made sports drinks. Recipes based on tea with added carbohydrates do not contain acidity [14]. Self-made drinks based on fruit juices may contain significant acidity, whereas those based on syrup may have a low pH but low titratable acidity, indicating rather uncritical dental erosive potential.

The titratable acidity of the gels seems to be as variable as with the drinks. If gels are more or less directly swallowed without significant contact to the teeth followed by water rinsing, the erosive potential may potentially be reduced compared to the ingestion of the same amount of carbohydrates by a drink. However, there are no data available to validate this hypothesis.

Products with outstanding high titratable acidity are the tested energy drinks indicating an extraordinarily high erosive potential on dental enamel. Athletes using energy drinks on a regular basis should be aware that these drinks are neither optimized for athletes (e.g., inappropriately high osmolality for consumption during sports) nor are they good for oral health.

Osmolality

In contrast to our market screening in 2006, the osmolality values seem to have lowered. On the one hand, product recipes have clearly been changed since then. E.g., a decade ago, most Gatorade sports drinks showed osmolality values higher than 300 mosmol/kg, with some flavors up to 362 mosmol/kg. In the present survey, the values have come down to 218–301 mosmol/kg. This osmolality change came without a difference in the carbohydrate content. The Powerade sports drink flavored "Mountain blast" improved its osmolality from 391 mosmol/kg in 2006 to 285 mosmol/kg in the present survey. On the other hand, new products with hypotonic osmolality have entered the market with some of them specifically marketed as "hypotonic". Today, athletes have a wide range of sports drinks available with osmolality far below 300 mosmol/kg. This is in contrast to our 2006 screening in which most available products showed osmolality values higher than 300 mosmol/kg.

There was no clear correlation between the carbohydrate content and osmolality. Products with an increased content of maltodextrin or hydrolyzed starch (e.g., Carbo basic from Winforce) may contain significant carbohydrates with a concomitant low osmolality. Hence, within the range of typical carbohydrate concentrations for sports drinks, the average chain-length of included carbohydrates significantly controls osmolality.

Interestingly, domestic food regulations have changed in 2017. In 2006, a sports drink could be labeled as "isotonic" when osmolality was in the range of 250–340 mosmol/kg. In contrast, present regulations allow the term "isotonic" for products with an osmolality range of 270–290 mosmol/kg and "hypotonic" for osmolality of 260 mosmol/kg or below. Both in 2006 and today, several products sold as isotonic did not fulfill the regulations. However, it is unclear whether the presently narrow definition for an isotonic drink makes sense from a physiological point of view. Several products exhibit greater variation between different flavors of the same product than food regulations allow. There is no physiologic argument that would indicate any meaningful physiologic effect of osmolality changes as low as 20 mosmol/kg.

Finally, osmolality, pH and titratable acidity are only selected aspects of sports drinks among many others. Albeit physiologic parameters like gastric emptying and fluid absorption can be influenced by the osmolality of a consumed drink, other factors may be more significant, e.g., the carbohydrate concentration of the drink [12]. And even if the pH and the titratable acidity do have substantial and relevant effects on dental erosion, oral health does by far not only depend on the acidity of the consumed sports drinks. Further, e.g., taste preference or individual gastrointestinal tolerance are certainly further substantial arguments for an athlete's choice. The provided pH, titratable acidity, and osmolality data can help athletes to find the most suitable drink for their specific situations and requirements.

Conclusion and practical implications

Domestic and international sports drinks and gels available on the Swiss market vary widely in their pH, titratable acidity, and osmolality. Hence, different products feature significantly different dental erosive potential. Over the last decade, several drinks with considerably reduced osmolality and acidity have entered the market and recipes have been updated. Today, athletes can choose from a variety of products with low acidity and optimized osmolality. Athletes who prefer acidic products are advised to have a special focus on oral hygiene and the regular application of fluoridated products to mitigate dental erosion from acidic drinks.

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