Rocz Panstw Zakl Hig 2017;68(2):167-173

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ORIGINAL ARTICLE

BEVERAGE OSMOLALITY AS A MARKER FOR MAINTAINING APPROPRIATE BODY HYDRATION

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ABSTRACT

Background. Osmolalities can be useful markers for determining whether given beverages are suited for maintaining an adequate hydration of the body. Losing 2% of body water relative to body mass reduces the efficiency of body function when undertaking physical effort by around 20%. Deficiencies in water intakes approaching 5-8% of body mass, double the impairment to the body's physical and mental functioning, whereas at a level of 10% the body becomes incapable of performing any sort of physical effort. For such reasons the body's hydration status is vital to its functioning.
Objectives. To asses osmolalities as measured in various types of commercially available mineral waters and non-alcoholic beverages containing different amounts of extracts.
Materials and Methods. Test materials were commercially available mineral waters (of low, medium and high mineral content) along with juices, nectars and drinks that are isotonic, energising and those described as being 'light' and sparkling. Osmolality was measured by the 800CL Osmometer instrument from TridentMed whilst the RL-type refractometer was used for determining extract values.
Results. Isotonic drinks were found to have the same osmotic pressures as bodily fluids at 275 – 295 mOsm/kg water. The osmotic pressure in mineral waters depended on the extent of mineralisation and ranged from 13 mOsm / kg water (low mineral content) to 119 mOsm/kg water (high mineral content). Low osmolalities were also found in 'light' drinks (from 29.3 to 34 mOsm/kg water). Juices, nectars, energising drinks and colas typically have high sugar contents and have high osmolalities ranging 492 – 784 mOsm / kg water. Statistical analysis demonstrated significant associations ($p < 0.05$) between osmolalities and extract content in beverages as well as between osmolalities and mineral content in mineral waters. Upon factor analysis, it was possible to group the tested drinks according to similar osmolalities and extract content.
Conclusions. Osmolalities measured in beverages are a marker that permits drinks to be classified into groups according to their tonicity and their ability to ensure that the body is properly hydrated; this becoming vital in cases when the body requires rapid body fluid replenishment.

Key words: *body hydration, osmolality, extracts, non-alcoholic drinks/beverages.*

STRESZCZENIE

Wprowadzenie. Wartość osmolalności napojów może być wykorzystana jako wskaźnik ich przydatności do właściwego nawadniania organizmu. Utrata wody w wysokości 2% w stosunku do masy ciała obniża wydolność fizyczną o około 20%. Niedobór wody sięgający 5-8% masy ciała powoduje dalsze zaburzenia wydolności fizycznej i psychicznej, a przy stracie wody do 10% masy ciała człowiek jest niezdolny do wykonywania jakiegokolwiek wysiłku fizycznego. Dlatego też kontrola stanu nawodnienia organizmu jest bardzo istotna.
Cel. Celem badań była ocena zmierzonej osmolalności różnych wód mineralnych (nisko, średnio i wysoko zmineralizowanych) oraz soków, nektarów, napojów izotonicznych, energetyzujących, „light" i gazowanych zawierających różne zawartości ekstraktu ogółem (^{o}Bx).
Materiał i metody. Materiał do badań stanowiły komercyjnie dostępne wody mineralne (nisko, średnio i wysoko zmineralizowane) oraz soki, nektary, napoje izotoniczne, energetyzujące i „light" oraz gazowane o różnej zawartości ekstraktu. Osmolalność oznaczono przy wykorzystaniu osmometru 800 CL firmy Trident Med., natomiast zawartość cukrów mierzono refraktometrem typu RL. Wyniki poddano analizie statystycznej wykorzystując program Statistica v. 12.
Wyniki. Stwierdzono, że napoje izotoniczne charakteryzowały się typowym dla płynów ustrojowych ciśnieniem osmolalnym (275-295 mOsm/kg H_2O). Ciśnienie osmolalne wód mineralnych zależało od stopnia ich mineralizacji i wahało się od 13 mOsm/kg H_2O (nisko zmineralizowane) do 119 mOsm/kg H_2O (wysoko zmineralizowane). Niską osmolalność wykazywały także napoje typu „light" (od 29,3 do 34 mOsm/kg H_2O). Soki, nektary, napoje energetyzujące oraz napoje typu „cola" charakteryzujące się wysokim udziałem cukrów wykazywały wysoką osmolalność wynoszącą od 492 do 784 mOsm/kg H_2O. Analiza statystyczna wyników wykazała, że istnieje istotna zależność ($p < 0,05$) pomiędzy osmolalnością

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a zawartością ekstraktu ogółem w napojach, a w wodach mineralnych pomiędzy osmolalnością a zawartością składników mineralnych. Analiza czynnikowa pozwoliła na pogrupowanie badanych napojów produkowanych przemysłowo wg podobnej osmolalności i zawartości ekstraktu ogółem na grupy o podobnej osmolalności i zawartości ekstraktu ogółem.
Wnioski.. Osmolalności zmierzone w napojach są markerami, które pozwalają klasyfikować napoje według grup w zależności od ich toniczności i ich zdolności do zapewnienia, że organizm jest odpowiednio nawodniony. Staje się to niezbędne w przypadkach, gdy organizm wymaga szybkiego uzupełnienia płynu ustrojowego.

Słowa kluczowe: *osmolalność, ekstrakt, napoje bezalkoholowe*

INTRODUCTION

The osmolalities of beverages can be used as markers of their usefulness for achieving appropriate hydration of the body. Whenever fluid intakes become limited or if an uncompensated large water loss occurs, then firstly plasma volume becomes reduced and sodium concentration rises, as does the osmolality. If such water deficiencies are not replenished, water moves out of cells into the extracellular space in order that osmotic equilibrium be maintained. This results in intracellular dehydration, which physiologically manifests itself by thirst, impaired salivation, dry mouth, irritability, insomnia, skin redness, loss of appetite, physical weakness, and abnormal motor coordination. Urinary volume is also decreased along with the excretion of waste metabolic products (urea, creatinine and others), thereby causing body toxicity. When fluid intakes are too low, sweating is reduced, which at high ambient temperatures can cause body overheating. A 2-3% water loss to the body mass lowers physical efficiency by about 20%, whilst water deficiencies of up to 5-8% of body mass results in further deterioration of physical and mental function, and if such water losses are 10% of body mass, a person becomes incapable of exercising any physical effort whatsoever [5]. Therefore, control over the body's hydration is very important. Two factors that predominantly lead to premature exhaustion, are linked to the body's depletion of carbohydrate stores and the loss of water and electrolytes through sweating. Drinking sports drinks, whose main aims are to prevent dehydration and provide energy and electrolytes, can thereby increase the body's functional efficiency [15].

The market for non-alcoholic beverages is always changing in the assortment and intended use of its products, that is conditioned by the expectations and needs of various consumer groups. Drinks are sought for that can quickly quench thirst but simultaneously also supplement body fluids that are lost during intense physical exertion or because of high ambient temperatures; these are isotonic fluids, ie. fluids with an osmotic pressure similar to that of body fluids where the osmolality ranges 275 to 295 mOsm/kg of water. Such drinks are especially recommended to those performing high levels of physical activity, including athletes [12]. They shore-up water deficiencies and restore the body's electrolyte balance.

The different types of energy drinks constitute a significant part of the beverage market and are chiefly intended for people performing high levels of mental activity. Such drinks increase reaction to stimuli? rates and bodily function, enhance mental concentration, counteract fatigue and accelerate metabolism. The non-alcoholic drinks market also consist of fruit juices and nectars which, together with energy drinks, belong to the group of hypertonic beverages with an osmolality higher than 295 mOsm/kg of water. These contain varying amounts of sugars, organic acids, vitamins and minerals and they are absorbed more slowly than water where they contain far more solid material than bodily fluids. Their main task is to supply the body with energy after physical activity. Hypertonic drinks are not recommended to athletes because they reduce the rate of water absorption and may increase the risk of suffering from diarrhoea and gastrointestinal discomfort. Nevertheless they can be drunk in limited quantities after exercise for renewing glycogen stores [12, 15].

Various types of mineral water and beverages known as 'light' have an osmolality of less than 275 mOsm/kg of water and belong to the group of hypotonic drinks. They are especially recommended whenever the so-called hypo-osmotic dehydration occurs, consisting of an excessive loss of excreted water and minerals relative to intake. Hypotonic drinks are rapidly absorbed into the body, sometimes even faster than water. Compared to the other drinks, they contain less sugar, quickly hydrate the body and quench thirst. When also compared to isotonic and hypertonic drinks, they are however unable to rapidly improve the body's water-electrolyte balance due to their lower electrolyte concentration [2]. Hypotonic drinks and mineral water are recommended for those doing moderate amounts of work and not too intensive nor prolonged exercise, which does not generate high levels of sweating [9].

Knowing the osmolality of any given beverage enables appropriate choices to be made for any given situation arising; for example when body fluids need to be quickly replenished after any losses have been incurred. Whilst the content and types of carbohydrate are labelled on the drink's packaging, osmolalities are not provided. In this study, we have therefore measured osmolalities in commercially available mineral waters and non-alcoholic drinks of varying extract content.

MATERIALS AND METHODS

Study materials for testing

These were commercially available mineral waters and other non-alcoholic beverages. Their characteristics are shown in Table 1.

Test methods

Immediately after being opened, samples of the above were taken for measurements of osmolality and total extract content; each being performed in triplicate.

Measuring osmolality

The osmolality of beverages were measured, in triplicate on the OS-3000 osmometer. Samples were degassed then cooled until the moment of crystallization thereby forming a biphasic system; liquid and ice crystals. The heat of crystallization maximally raised the system temperature to its freezing point from which the osmolality of the sample was determined from the freezing point depression; with the results being displayed on the osmometer and calculated as mOsm per kg water.

Measurement of total extract

A refractometric method was used by means of a RL type Refractometer and performed at 20 ºC.

Statistical analysis

All results were analysed using the STATISTICA v. 12 computer program, where standard deviations were calculated along with one-way analysis of variance (ANOVA) and factor analysis.

Table 1. Characteristics of commercially available mineral waters and other non-alcoholic beverages used in the study; as taken from product labels.

Mineral waters of low mineralisation	A	High CO_2 saturation; total mineral content 311.5 mg/l
	B	High CO_2 saturation; total mineral content 285.8 mg/l
	C	High CO_2 saturation; total mineral content 322.2 mg/l
	D	CO_2 unsaturated; total mineral content 420.0 mg/l
Mineral waters of medium mineralisation	A	CO_2 unsaturated; total mineral content 714.0 mg/l
	B	High CO_2 saturation; total mineral content 508.6 mg/l
	C	CO_2 unsaturated; total mineral content 942.9 mg/l
	D	CO_2 unsaturated; total mineral content 946.51 mg/l
Mineral waters of high mineralisation	A	CO_2 unsaturated; total mineral content 5525.3 mg/l
	B	CO_2 medium saturated ; total mineral content 1890.7 mg/l
	C	CO_2 unsaturated; total mineral content 1547.5 mg/l
	D	CO_2 unsaturated; total mineral content 2087.8 mg/l
Isotonic drinks	A	Lemon flavoured; total mineral content 62.1 mg/100 ml; carbohydrate content 6.7%
	B	Orange flavoured; total mineral content 64.4 mg/100 ml; carbohydrate content 5.6%
	C	Lemon flavoured; total mineral content 120 mg/100 ml; carbohydrate content 5.7%
	D	Citrus fruit flavoured; total mineral content 141.6 mg/100 ml; carbohydrate content 5.7%
Energising drinks	A	Containing taurine (0.4%), caffeine (0.03%), inositol, vitamins (niacin, pantothenic acid , B6, B12); carbohydrate content 11%
	B	Containing: caffeine, guarana extract (0.02%); carbohydrate content 11%
	C	Containing: taurine (0.4%), caffeine (0.03%), vitamins (niacin, pantothenic acid , B6, B12), inositol, glucuronolactone; carbohydrate content 11.3%
	D	Containing: taurine (0.4%), glucuronolactone (0.2%), caffeine (0.03%), inositol (0.02%), vitamins (niacin, pantothenic acid , B6, B12); carbohydrate content 11.3%
Juices & nectars	A	Blackcurrant flavoured nectar with blackcurrant juice concentrate (25%)
	B	Orange flavoured juice with orange juice concentrate
	C	Multivitamin juice from concentrates and purees (20%) from: apples 11.9%, oranges 5.5%, grapes, pineapples, lemons, apricots, bananas, guava, mango, peaches, grapefruits and limes
	D	Orange flavoured juice with orange juice concentrate
‘Light’ drinks	A	Pepsi ‘light’; sweeteners: aspartame, acesulfame K
	B	Coca-Cola ‘light’; sweeteners: cyclamates, acesulfame K, aspartame
	C	Grapefruit-orange flavoured drinks containing juice concentrates of: grapefruit (20%), oranges (5%) and sweeteners - saccharin sodium, sucralose and acesulfame K
	D	Pineapple-grapefruit flavoured drinks containing juice concentrates of: pineapple(17%), grapefruit (8%), and sweeteners - saccharin sodium, sucralose and acesulfame K.
Other sparking drinks	A	Pepsi, containing sugar (11%), carbon dioxide, acid (phosphoric acid) and caffeine.
	B	Coca-Cola, containing sugar (10.6%), carbon dioxide, phosphoric acid and caffeine.
	C	Sprite, containing sugar (10.6%) glucose-fructose syrup, carbon dioxide, citric acid, sodium citrate and malic acid.
	D	Orangeade, containing sugar (8.6%) and/or glucose/fructose syrup, carbon dioxide, citric acid and black carrot concentrate.

RESULTS

The osmolalities of mineral waters, along with the mineral compositions as provided by the manufacturers are shown on Table 2. These osmolalities varied according to the extent of mineralisation, ranging from 20 mOsm/kg (low-mineralised water) to 119 mOsm/kg of water (highly mineralised water), with the statistics confirming this as shown in Table 3.

Table 2. Osmolalities of tested mineral waters.

Mineral water type		Osmolality [mOsm/kg water]		Total mineral content (from product labels)
		X	SD	
Low mineralisation	A	28	1.53	311.5
	B	20	1.53	285.8
	C	28	0.58	322.2
	D	20	0.58	420.0
Medium mineralisation	A	75	1.53	714.0
	B	44	2.00	508.6
	C	54	1.00	942.9
	D	58	0.58	946.9
High mineralisation	A	119	1.53	5525.3
	B	75	0.58	1890.7
	C	69	1.73	1547.5
	D	88	0.51	2087.8

X – Mean; SD – Standard deviation

Table 3. Mineral waters divided into homogenous groupings according to osmolality.

Mineral water type	Osmolality [mOsm/kg water]	Homogenous grouping		
		1	2	3
Low mineralisation	24.00	****		
Medium mineralisation	57.75		****	
High mineralisation	87.75			****

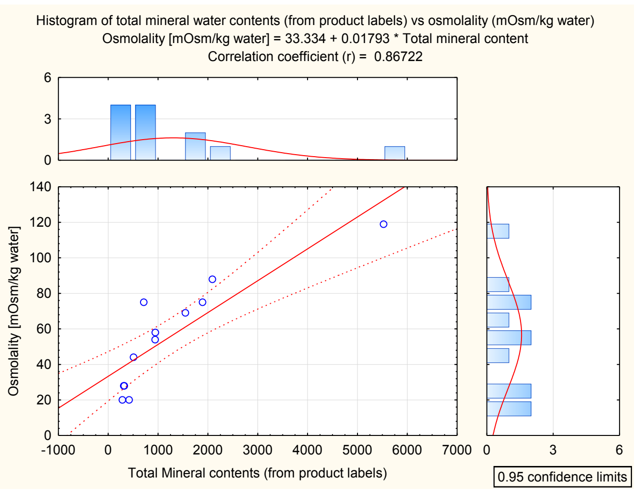

Figure 1. The association between osmolality and total mineral content in mineral waters

Mineral water osmolality significantly rose as the mineral content increased ($p < 0.05$). The total mineral content of the mineral waters was highly correlated ($r=0.86$) with their osmolality (Figure 1).

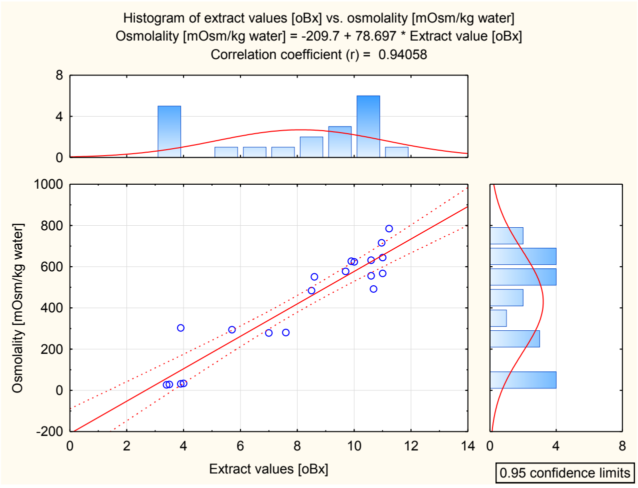

Figure 2. The association between extract values and osmolality in tested beverages

Table 4. Osmolalities and extract contents in non-alcoholic beverages

Type of beverage		Osmolality [mOsm/kg water]		Extract values [ºBx]	
		X	SD	X	SD
Isotonic	A	279	1.73	7	0.06
	B	304	2.52	5.6	0.08
	C	294	7.57	5.7	0.05
	D	281	3.61	7.6	0.09
Energising	A	567	1.53	11	0.12
	B	484	5.03	8.5	0.05
	C	645	5.03	11	0.05
	D	784	6.03	11.23	0.05
Juices & nectars	A	624	1	10	0.04
	B	577	2.52	9.7	0.09
	C	626	0	9.9	0.05
	D	716	1.53	10.97	0.05
‘Light’ drinks	A	34	1.73	4.00	0.05
	B	29	4.73	3.50	0.09
	C	28	1.53	3.40	0.12
	D	32	1.53	3.90	0.05
Other sparkling drinks	A	492	3.21	10.68	0.05
	B	632	1.53	10.6	0.1
	C	556	2.31	10.6	0.05
	D	551	4.16	8.6	0.05

The measured extract content values and osmolalities of the various groups of commercially available drinks groups are shown in Table 4, with extract values ranging from 5.6 (isotonic drinks) to 11.23 (energy drinks), where these values are characteristic for the beverage type. Large variations were observed in the extract contents of the drink groupings. Isotonic drinks had fairly low extract contents ranging from 3.90 to 7.60 °Bx and had normal osmolalities (excepting B), that fell within the range found in body fluids (275-295 mOsm/kg water). Energy drinks, juices, nectars and sparkling beverages showed high osmolalities, ranging from 484 to 784 mOsm/kg water for energy drinks, from 577 to 716 mOsm/kg water for juices and nectars and from 492 to 632 mOsm/kg water for other sparkling beverages. The osmolalities of 'Light' drinks were approximately those of the medium-mineralised mineral waters. Statistics confirmed the variability of osmolalities in the drink groupings tested and Table 5 presents the distribution of osmolalities according to their homogeneous groupings. The first group were hypertonic drinks (colas, energy drinks, juices and nectars), the second were light drinks and thirdly the isotonic drinks. Extract content values significantly increased with rising osmolalities, ($p<0.05$), with the correlation coefficient being 0.94, thereby indicating a strong association between the extract contents values and the beverage osmolality (Figure 2).

Table 5. Non-alcoholic beverages divided into homogenous groupings according to osmolality

Type of beverage	Osmolality [mOsm/kg water]	Homogenous groupings		
		1	2	3
'Light'	30.83		****	
Isotonic	289.50			****
Other sparkling drinks	557.75	****		
Energising drinks	620.17	****		
Juices & nectars	635.92	****		

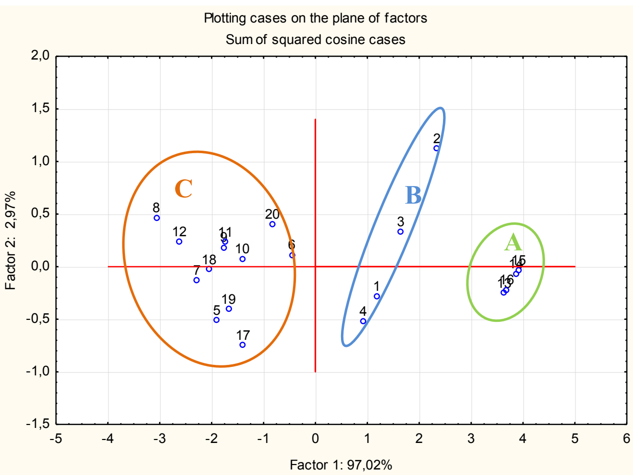

Figure 3. Biplot factor analysis grouping the non-alcoholic beverages according to similar osmolalities and extract content values

Factor analyses allowed the commercially available non-alcoholic drinks to be grouped into three of similar osmolality and total extract content (as shown in Figure 3); ie. light beverages classified as hypotonic drinks (A), isotonic drinks and energy drinks (B) and other carbonated drinks, juices and nectars (C) with high osmolalities characteristic of hypertonic beverages.

DISCUSSION

There is a great variety of commercially available drinks that are recommended for quenching thirst as well as making up any shortfalls in bodily fluids. However, osmolalities are not provided and thus a given drink's ability to replenish water and minerals, which are lost after different types of exercise, is unknown. For this reason our study has compared osmolalities of various commercially available drinks, such as mineral waters, isotonic drinks, energising drinks, 'light' beverages, other sparkling drinks and juices and nectars. Results show that three groups of beverages of similar tonicity can be distinguished as follows: hypotonic drinks, (which include mineral water and light beverages), isotonic drinks and hypertonic drinks (like energising drinks) and 'light' and sparkling beverages. In order that the body's water and electrolyte balance be restored, drinking isotonic fluids is vital as they contain similar amounts of osmotically active substances [19].

A study by *Saat* et al. (2002) investigated body mass fluctuations during intense physical activity causing sweating, and demonstrated that in 80% cases these can be minimised through drinking isotonic beverages containing carbohydrates and selected electrolytes. In commercially available isotonic drinks, apart from water, there are carbohydrates present (mainly glucose, fructose and sucrose) at around 6g/100 ml, sodium, potassium, (sometimes calcium or magnesium) and B group vitamins. In addition to the aforementioned carbohydrates, intensive sweeteners can be added. It is suggested that the extent of intestinal water absorption after drinking isotonic beverages is lower compared to hypotonic beverages, insomuch the latter provides an additional amount of electrolytes for restoring proper electrolyte balance in the body after intensive exercise [11, 15].

There is evidence to show that hypotonic drinks exhibit a higher intestinal tolerance compared to hypertonic drinks [1, 8, 16]. Our study showed that for hypotonic drinks, including mineral waters, their osmolalities depend on the extent of general mineralisation and the ratios between the various mineral components. The extent of mineralisation of the mineral waters is quantitatively expressed as their mineral content. According to these values the mineral waters were divided into three groups: low-mineralised water containing 1 l less than 500 mg of dissolved minerals, medium-mineralised water containing 1 l of 500-1,500 mg of dissolved minerals, and highly mineralised water containing 1 l of above 1500 mg dissolved mineral components [17]. 'Light' drinks were included in the hypotonic group. Their low tonicity, similar to medium-level mineral waters, resulted from replacing sugars by intense sweeteners; being mainly aspartame and acesulfame K.

The osmolalities of juices, nectars, energy drinks and colas are significantly influenced by the total extract content. *Mettler* et al. [15] reported that the osmolality of beverages rises with total carbohydrate content which highly depends on the proportions of monosaccharides, disaccharides and polysaccharides, together with the levels of organic acids, vitamins and minerals. The literature indicates that sugars' levels in beverages, their calorific value and osmotic activity affect the rates of gastric emptying and intestinal absorption [3, 7, 8, 13, 14]. Juices, nectars, energising drinks and colas are hypertonic fluids, whose consumption reduces the water absorption rates and cause fluid to pass from the plasma and intra-cellular fluid into the intestine, thus hindering proper hydration of the body. Drinking hypertonic drinks during physical exercise increases both the feelings of gastrointestinal discomfort and the risk of diarrhoea.

In contrast when hypertonic drinks are consumed at resting conditions, for example during breaks in exercise, then this does not usually cause any gastrointestinal discomfort. If a drink is to be consumed during exercise, where the risk of gastrointestinal complaints is higher than at rest, then the most appropriate osmolalities are those ranging 200-250 mmol/kg [15]. *Gisolfi* et al. [10] reported that drinking beverages containing 6% carbohydrates is beneficial; in such amounts there is no significant difference in the rates of gastric emptying relative to water. A study by *Burke* [8] aiming to maintain adequate hydration of the body, recommended consuming such drinks both before and during exercise, and in the shortest time immediately after physical activity. This study recommended drinking 4-8% carbohydrate-containing drinks and electrolytes after 60 minutes of physical activity. Nevertheless, drinks of high osmolality are not a cause for concern if achieving rapid hydration is not the main reason for their consumption. To reduce osmolality and increase water absorption, such drinks can be diluted with either water or other hypotonic fluids.

CONCLUSIONS

1. Commercially available mineral waters and non-alcoholic beverages demonstrated large variations in osmolality depending on their mineral content that of the total extract values.
2. Drinks with the highest osmolalities coupled with extract content values were found in energising drinks, other sparkling drinks, juices and nectars; these osmolalities ranging from about 557 to about 636 mOsm/kg of water, thus allowing them to be classified as hypertonic drinks.
3. In comparison, those drinks having the lowest osmolalities and total extract content were mineral waters and light beverages, (ranging from around 24 to around 88 mOsm/kg water), and were thus classified as being hypotonic drinks.
4. The osmolalities of the isotonic drinks tested, were similar to those of body fluids (ie. ranging from 275 to 295 mOsm/kg water).

Conflict of interest

The authors declare no conflict of interest.

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Received: 15.11.2016
Accepted: 14.03.2017