Sports drinks and their impact on dental health

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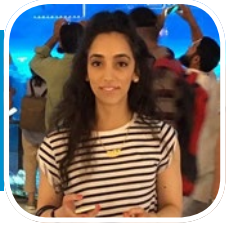

By **Laura Hinds**[1]

Introduction

Sports drinks were made for three main reasons: to prevent dehydration during sport or exercise; to supply enough carbohydrates to increase energy; and to provide electrolytes to replenish those lost during perspiration, with the view that these would be full of flavour.[1] These can then be split into two main types of solution: hypotonic and isotonic. The constituents of these drinks have different modes of action when consumed by athletes. Hypotonic mixes are less concentrated in comparison to fluids in the body, therefore these give quick absorption and rehydration which would be needed after an event. Isotonic mixes are more for replacing lost fluid and energy during competing. The ways in which this energy can be provided is through the form of carbohydrates; these are powdered and added to the mixes and can include glucose, maltose or dextrose, usually mixed with water. This is so the optimum carbohydrate and electrolyte balance/concentration is achieved.[2]

As a quick and easy means to rehydrate from an athlete's point of view, sports drinks – which supplement diet and training – are primarily used for rehydration after an event, or before an event in order to boost performance.[2]

Much focus on hydrating can be traced back to the boom in road running, which began with the New York marathon.[3] Sports drinks are associated with physical activity – it can be suggested that what is supposedly good for the health is not necessarily good for dental health; these may not be essentials for hydration when exercising. Sports drinks are becoming increasingly popular amongst the general community, the public and athletes alike, when it comes to rehydration. Often overlooked is the impact of this when it comes to dental health, and the rapidly increasing popularity of these drinks. This has particularly increased in the last couple of decades, amongst the public, primarily, and debatably, amongst adolescents.[4]

The earliest type of sports drink, established in the 1960s, was made up of water, sodium, sugar, and monopotassium phosphate with a 'dash of lemon flavouring'.[3] This emphasises, particularly to dental professionals, the dangers clinicians need to be aware of clinically when assessing patients, and how to effectively treatment plan for individuals' needs, given the type of ingredients that sports drinks contain.

It would be obvious to assume that the consumption of sports drinks increases not only the potential for erosion[5] as 'the nonbacteriogenic, acid-induced loss of tooth structure' but it would also heighten caries risk, where caries 'is caused by bacteria colonsing the tooth surfaces'.[6]

The effects of sports drinks on dental health is a topic which requires more research, particularly if you take into consideration the modern-day obsession with health and well-being, in addition to the lack of evidence and research, where sports drinks are no stranger to supermarket shelves.

It has been suggested that 'sports drinks have the same acidogenicity as fruit juice and carbonated beverages'[2] as well as (opposing) suggestions that there is no correlation showing sports drinks negatively impacting oral health,[5] such as through caries or erosion. This review will aim to investigate, through evidence-based evaluation, the impact sports drinks might have on dental health. It will

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also highlight the variety of sports drinks available, as well as the potential these have to detrimentally impact dental health.

Methodology

Research of the literature began between 15 October 2018 and 11 November 2018, using the following electronic platforms:

- UHI MultiSearch
- EBSCO Host (Academic Search Complete)
- Medline
- Wiley Online Library.

All literature focused on sports drinks, tooth wear and erosion. Search terms included: bodybuilding, dental, erosion, caries, sports drinks, supplements, dental.

The inclusion/exclusion criteria included: Only full text journal, review, research papers published in the last 30 years, papers of high hierarchy of evidence, written in English language only with no geographical limitations.

The review includes literature dated from 1997 to 2017. Twenty papers were found in total, with nine studies being excluded after reading the abstracts due to lack of relevance, as some focused more on the body composition and overall health as opposed to dental health. There were also factors such as studies being too dated, and newspaper articles, which do not sit on the hierarchy of evidence and would have been invalid.

The limitations were that there was a significant lack of randomised control trials, along with free access to studies. It also seems that the topic is either not widely researched or even overlooked as part of dental health.

All papers were analysed using *Nursing – a framework for critiquing quantitative research articles* by Oxford University Press.[7] From this, analysis and ideas were instigated, and therefore all papers chosen underwent evaluation, which will be discussed in this literature review.

Table 1 shows information on the study type, the type of sports drink and its erosive potential, as well as how this relates to current dental practice.

Review studies

This review aims to investigate the impact (if any) sports drinks have on dental health in athletes across a variety of sports.

The difficulty is that this is still a fairly recent topic which needs to be researched further; this has in some ways limited the evidence and literature found, particularly when placing it on the hierarchy of evidence. Despite the fact the majority of literature found are '*in vitro*' studies, it would be unethical to run trials on actual patients, with the potential to cause erosion or caries. This highlights that more research and awareness needs to be raised around this topic, given the rising popularity of sports drinks as a means of quenching thirst.

Because of these reasons, there are a limited number of randomised controlled trials which sit high at the top of the hierarchy of evidence, as 'researchers are inevitably more familiar with the multisite randomised controlled trial (RCT) "gold standard"'[8] compared to *in vitro* and cohort studies. It was decided that the aim would be to use as many RCTs as possible as best practice suggests for the topic at hand, as 'Randomised controlled trials have long been held up as the "gold standard" of clinical research'.[9] In this review, no RCTs have been included, which may be due to lack of research. Access to an RCT was attempted on the platform 'ResearchGate', however, this did not prove successful.

The remainder was made up of cohort studies, observational studies, and *in vitro*/laboratory studies (Table 1). These are not of the best practice and sit quite low in the hierarchy of evidence, however, it again relates back to ethics regarding clinical trials in addition to the fact that the concept is quite contemporary.

Despite numerous attempts as well, there were also limited books regarding this topic; this was also discounted when deciding on literature and papers.

The critical analysis phase of the literature review was based on quantitative research, and the most appropriate analysis tool was used (Holland and Rees framework).[7]

Results

The evidence base consisted of one pilot study, a review article, and two cross-sectional studies; the remainder were *in vitro* studies. Due to the studies being *in vitro* this significantly reduces the quality of the research found, and limits the extent to which the topic was researched; even though there is information gained, it is of limited depth and accuracy and so further research or primary research would need to be conducted to a much greater scale. This would not only improve the reliability of the research, but it would also mean that there is more awareness regarding the topic.

Six studies were conducted outside of Europe. Four from North America: Mathew, Casamassimo and Hayes (2002);[5] von Fraunhofer and Rogers (2005);[10] Wongkhantee *et al.* (2006);[11] Owens, Malette and Phebus (2014);[4] South America: Antunes *et al.* (2017);[12] Australia: Sirimaharaj *et al.* (2002);[13] Coombes (2005);[1] and Ramalingam, Messer and Reynolds (2005).[14]

Quantitative methods were largely used in studies; there were some qualitative methods also: Milosevic, Kelly and McLean (1997) used questionnaires to determine the sports drinks which were consumed, as well as the pattern of consumption.[2] With this, pH and titrable acidity, concentrations of calcium, phosphate and fluoride, as well as viscosity were analysed. The salivary flow rate of the individuals was also established. This study failed to show an association between erosive wear or caries and sports drink consumption. The study by Mathew, Casamassimo and Hayes (2002) is similar, in that sports drink usage, lifestyle, health problems, dietary and oral health were all analysed as factors in the self-administered questionnaires.[5] These were reviewed by an assistant and any discrepancies were clarified. The subjects were also partially interviewed and this was cross checked with trained examiners.

Through questionnaires and face to face questioning, this raises the concern of possible bias, where participants may have answered according to what the examiners wanted as opposed to what was true of them, which may have manipulated the results in a way that proved sports drinks are not detrimental to dental health.

There were also parts of the studies which encompassed quantitative methods; this is particularly true of the study by Mathew, Casamassimo and Hayes (2002);[5] in addition

> *'Sports drinks are becoming increasingly popular amongst the general population, the public and athletes, when it comes to rehydration'*

Table 1 A table to show the main findings of the literature in review

MAIN FINDINGS				
Author	**Type of study**	**Type of sports drink**	**Erosive potential**	**Relation to practice**
Milosevic *et al.* 1997[2]	Descriptive study	High 5, Isostar, Maxim, PSP22	Potential for erosion – more so amongst swimmers – some evidence of wear into dentine	Tooth wear must be (or should be) monitored, especially as sports drinks are an aetiological factor in dental erosion
Mathew T *et al.* 2002[6]	Observational, cross-sectional study	Not known	No relationship between any of the sports drinks which related to dental erosion, with several athletes tested who had a high consumption of sports drinks	Further studies in erosion, especially with regards to susceptibility, early diagnosis, aetiology, treatment and prevention
Ramalingam L *et al.* 2005[14]	In vitro study	Powerade	Erosion can be prevented/limited by adding the correct concentration of CPP-ACP	The taste (palatability) of the modified sports drink should have further evaluation- with taste testing panels
Bamise C *et al.* 2012[16]	In vitro study	B Star Energy Drink, London Best Energy Drink, Hippo Energy Drink, Lucozade Boost Energy fast, Hype Energy, Vita 500 Energy Drink, Lucozade Sport, Power Horse Energy Drink, Red Bull Energy Drink	'Acidic drinks and foods lower the pH level of oral cavity hence their consumption causes the teeth to demineralise'[16]	Dental practitioners should monitor patients for the consumption of sports and energy
Owens B *et al.* 2014[4]	In vitro study	Red Bull Energy Drink and Gatorade	Differences between tested drinks with regards to pH - Red Bull: the greatest erosive potential. But both drinks displayed evidence of affecting weight of tooth enamel	The constant exposure to these types of drinks has the potential to cause loss of tooth structure – this is particularly true of children and adolescents. Athletes also have a higher risk of enamel loss or damage, as they are consuming these when dehydrated
von Fraunhofer J A *et al.* 2015[10]	Article of a pilot study	Various acidic drinks (such as Coca-Cola and Dr. Pepper) none were sports drinks	N/A to this literature review but showed that the presence of carbohydrates – for example, sugar, in a drink – does not affect enamel dissolution	Not known
Coombes J S 2005[1]	Review of literature of sports drinks and dental erosion	Gatorade, Powerade, Allsport, Hydrafuel, Sport Plus, Isosport	This review of literature has reviewed evidence already mentioned in this table	

Table 1 A table to show the main findings of the literature in review

Wongkhantee S *et al.* 2006[11]	In vitro study	Not known	Does not specify that there was evidence of erosion, but states that the hardness of enamel had decreased significantly after being immersed in the sports drink	There is low public awareness (as well as with the other drinks tested, including orange juice and drinking yoghurt)
Sirimaharaj V *et al.* 2002[13]	Scientific article	Not known	From the questionnaires, sports drinks were the third most popular consumed, most often drank in between meals There was an apparent increase in the risk of erosion when the sports drinks were consumed at least once per week, however, this is not related in this particular study/article	More preventative programmes are needed, in addition to dietary counselling for young athletes
Antunes L S *et al.* 2017[12]	Cross-sectional study The Eccles Index was used to assess erosion – could be biased due to uncertainty when diagnosing erosion	Not known	The consumption of sports drinks was not associated with dental erosion, but dental erosion amongst amateur runners had an association with the frequency of running each week, as well as the time spent during a competition, in addition to the gastroesophageal reflux which played a part in dental erosion	Does not say
Hooper *et al.* 2004[15]	Controlled, crossover study	Not known, but included a test drink also (validates the reliability)	No evidence of loss of enamel from the specimens during this study The addition of calcium into sports drinks has the ability to reduce erosive formulations in sports drinks	Not known

to the above methods, the method of data analysis included clinical examination of the test results, which included using a stepwise linear regression using SPSS version 10 for Windows.

Ramalingham *et al.* (2005)[14] also used quantitative methods; 15 specific specimens were prepared and the numerical data were inputted into spreadsheets and analysed also using SPSS for Windows and Excel. The mean values were compared: pH and titrable acidity of the test and control solutions, as well as the mean depths of erosive steps.

Throughout, and in the studies highlighted, there was a dependent variable for analysis - there was a test and a control group where results were analysed and compared which increased the reliability of the papers being analysed. Consent was also largely gained throughout, which made the trials more valid.

The research gathered highlights many areas in that sports drinks play a limited part in affecting dental health in a negative way, as 'the erosive potential for sports drinks is real',[2] it has brought to light that more needs to be done in Europe in the way of prevention, especially amongst the younger generation. The following results highlighted this and were not what one would assume would be the case; this proves that there is perhaps a general ignorance to what the general public, particularly adolescents, consume, but then again, this could be due to the fact that there is a large market for this type of beverage.

In vitro **studies**

These studies all had similar aims for carrying out the studies: that the prevalence of erosion is on the increase, and the main reason behind this is the fact that sports drinks in particular are increasing in popularity amongst the general public as well as amongst athletes. This shows that the studies are all consistent in that there is continuity amongst them all in their aims/backgrounds and no differing in belief.

Milosevic, Kelly and McLean (1997)[2] discovered that 'the effect these sugars may have on the dental health of sports men and women has received scant attention in the British dental literature' (p 303); even though this study was conducted over 20 years ago, the more recent literature by Mathew, Casamassimo and Hayes (2002)[5] and Antunes

et al. (2017)[12] support this statement. This highlights it has been a problem for the last two decades or so; there needs to be much more awareness with regards to the topic.

Most of these studies had small sample sizes, in particular the study carried out by Milosevic, Kelly and McLean (1997)[2] had a sample size made up of 25 swimmers, 20 cyclists and ten volunteers, so a sample size of 55 overall participants. Similarly, Ramalingham *et al.* (2005)[14] had a sample size of 15 teeth, 20 tasters and four different strengths of concentration drinks Casein Phosphopeptide-amorphous Calcium Phosphate, (CPP-ACP), with one test drink which was Powerade. In contrast, the study by Mathew, Casamassimo and Hayes (2002)[5] had a sample size of 304 athletes who underwent analysis. This perhaps does limit and question the reliability of the papers because it only shows a limited amount of tested evidence; there are fewer results with which to make comparisons. It would have been beneficial to repeat the studies a few times to see if there was continuity with the results despite the small samples.

A continuous theme with regards to the strengths of the papers was that out of the seven *in vitro* studies, three had no mention of gaining ethical approval/ethical considerations. It was creditable that the majority did gain ethical approval, even though the participants were only being questioned either via questionnaire or face to face.

The main findings of all of the *in vitro* studies were much the same, in that there was some effect on the weight of the tooth/loss of enamel, but not enough to qualify as dental erosion. This was done by recording the weight of extracted teeth which had undergone thorough checking for ailments such as calculus/caries. They were then immersed in various sports drinks, and re-weighed after being immersed for a period of time.

Wongkhantee *et al.* (2006)[11] found that there was some decrease in the hardness of enamel after it had been immersed in sports drink. The study by Ramalingam *et al.* (2005)[14] found that adding the ingredient CPP-ACP at the correct concentration to sports drinks, would reduce erosion depths that the tooth would be exposed to, highlighting that this may be something sports drinks companies are already undertaking, as there is a common theme of erosive potential throughout the studies, as opposed to a definite cause or factor of erosion. This shares a similar view with Hooper *et al.* (2004),[15] in that the study concluded with the manipulation of sports drinks with calcium as well as adjusting the pH accordingly, this can significantly reduce erosive potential. This is further supported by Antunes *et al.* (2017),[12] in that the study concluded that there was no association of dental erosion with the consumption of isotonic sports drinks, but rather gastroesophageal reflux was more of a risk factor.

Bamise and Oderinu (2013)[16] raise questions with regards to reliability: no ethical approval was gained. This may not be of too much concern as the study was not carried out on teeth. It is this reason which questions its reliability, as the other studies were completed on extracted teeth or included amateur athletes. One strength of the study was that it included the actual types of sports drinks, which included: 'B Star Energy Drink; London Best Energy Drink; Hippo Energy Drink; Lucozade Boost Energy fast; Hype Energy; Vita 500 Energy Drink; Lucozade Sport, Power Horse Energy Drink; Red Bull Energy Drink'. Across the evidence base, there were few studies that included the names/brands of sports drinks.

> *'The idea that the sports drinks are for exercising/training purposes makes the studies more valid, as it shows continuity across the studies…'*

Cross sectional studies

A cross-sectional study, defined by Lavrakas (2008),[17] is a survey whereby data are collected 'to make inferences about a population of interest (universe) at one point in time. Cross-sectional surveys have been described as snapshots of the populations about which they gather data. Cross-sectional surveys may be repeated periodically'.

The study by Antunes *et al.* (2017)[12] had a sample size of 108 subjects. Ethical approval was gained by the Committee for Ethical Research of the Fluminese Federal University, which was agreed with ethical guidelines.[12] This included ten pretesters who were not included in the second phase of the study. This strengthens the overall research, since it has gained ethical approval therefore the study is legitimate; it could be argued that the pretesters should be included the second time also, as these results can always be disregarded.

The fact that there were overall 98 participants makes the study more reliable and trustworthy; even though it is still quite a low sample size, in comparison to the other literature this is quite a high number and therefore comes with more reliability for this reason as there is a higher number being tested. It could be suggested that for this reason the results may also be generalised; the results may have gone with the majority; therefore, the accuracy could be flawed.

The same study by Atunes *et al.* (2017)[12] included a face-to-face questionnaire which was initially delivered to all subjects. This was run a second time, a month later. This included: age of the subjects, gender, type of sport they practised, time they spent training, use of (any) isotonic sports drinks, toothpaste used and tooth brushing habits. This would impact results and affect reliability – the fact that the subjects have been questioned face to face removes any anonymity, so subjects may have lied in order to not give any incorrect answers which hinders the true results.

The fact that the studies also chose amateur athletes strengthens the reliability of the literature; the idea that the sports drinks are for exercising/training purposes makes the studies more valid, as it shows continuity across the studies. It could be assumed that professional athletes consume a higher amount of sports drinks as this is their full-time job.

The study by Coombes (2005)[1] could be questioned on its validity and the reliability of results as it used bovine teeth as part of the study raising issues of applicability to human teeth, as it is of course humans who will be consuming the drinks.

Discussion

A lack of association between erosive tooth wear and sports drinks consumption was concluded in the study by Milosevic, Kelly and McLean (1997),[2] which shares similar observations to studies by Mathew,

Casamassimo and Hayes (2002),[5] where athletes did not show any evidence of dental erosion, where the consumption of sports drinks was also at a high rate. Studies by Coombes (2005),[1] Wongkhantee *et al.* (2004),[11] Sirimaharaj, Messer and Morgan (2002),[13] and Antunes *et al.* (2016)[12] all share similar conclusions with the previous two studies; the overall findings in summary were that the acidic nature of sports drinks has the potential to cause dental erosion, however, saliva control and frequency of consumption – habit, is more important in this instance. In addition, it was the studies agreed that enamel surface was softened by sports drinks once consumed but did not qualify as erosion; there was no correlation with sports drinks and dental erosion. In addition, Antunes *et al.* (2016)[12] highlights the fact that with the use of isotonic sports drinks, there is no association with dental erosion.

The study by Owens, Phebus and Mallette (2014)[4] was conducted with six assorted drinks tested with water as the control, using recently extracted teeth – maxillary and mandibular primary and permanent teeth. All teeth were free from any conditions such as hypocalcification and caries; macroscopic fractures were also checked for, and the teeth were cleaned of any calculus or other debris. This strengthens the results as the study was conducted in a formal manner, ensuring it was as fair as could be. This study found that Red Bull had the highest titrable acidity, similar to the findings by Ramalingham, Messer and Reynolds (2005),[14] which then showed in the overall results, along with Gatorade, that there were higher levels of enamel loss once teeth had been weighed post immersion in solution in comparison to the other beverages which were tested, such as Coke. The study then concluded that Gatorade has a low pH.

Throughout the analysis phase, studies by Ramalingham, Messer and Reynolds (2005)[14] found that there were signs of erosion caused by Powerade; this was shown through the titrable acidity of the solution in comparison to the test solution, and so the pH decreased therefore becoming more acidic; however, this could be eliminated by adding 0.09%-0.25% concentration of CPP-ACP. This is the only evidence throughout the whole review that demonstrates this, which questions the reliability as it seems to be an isolated finding across all of the literature found.

Overall, amongst all of the evidence bases – apart from the study by Owen, Mallette and Phebus (2014)[4] - the drinks Red Bull and Gatorade showed much higher levels of enamel percentage mean weight loss in comparison to the other drinks tested – highlighting the erosion these drinks created. Therefore, once teeth had been immersed and re-weighed, the loss of enamel was greater than when tested against the control solution over a 10-day period. The remainder suggest that sports drinks have erosive potential but that it is not the main primary factor in dental erosion.

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'The literature were all in agreement that sports drinks have erosive potential but it is not necessarily the main factor in dental erosion and tooth wear'

Another interesting finding was that caries was only mentioned in the study by Milosevic, Kelly and McLean (1997)[2] but was not discussed in any of the evidence when sports drinks were mentioned; this shows that there are other beverages and foods – as shown in the evidence base – that have posed a higher risk of dental erosion and caries (dental diseases), which is not immediately obvious; for example, orange juice and other fruit juices are able to alter the structure of teeth when consumed.

It was interesting to see the study by Ramalingam *et al.* (2005)[14] was able to manipulate the structure/formula of the sports drinks by adding in an element – Casein Phosphopeptide-amorphous CPP-ACP at the correct concentration, after having trialed four different strengths of this. This proved the overall theory of all papers that sports drinks only have the potential to cause erosion but is not the primary factor in its origin.

The majority of all of the papers show that sports drinks are not the primary cause of dental erosion, but are a risk factor in the prevalence of the disease. Dental erosion can be caused either by intrinsic or extrinsic factors, sports drinks being the latter.

It could be suggested that in future studies Non-Carious Tooth Surface Loss/ Basic Erosive Wear Examination (NCTSL/BEWE) grading would be more relevant should the studies see more damaging results, which could also be included in caries.

Conclusion

Overall, the literature reviewed was largely in agreement that sports drinks have erosive potential but they are not necessarily the main factor in dental erosion and tooth wear.

Despite this, the papers in review were all fairly low in the hierarchy of evidence, which questions the validity of the studies, but also highlights the fact that more research needs to be carried out with regards to this topic, as the studies show within the last two decades. In this time, there have been minimal changes with regards to the way sports drinks are manufactured and marketed - there is still a high prevalence particularly amongst teenagers that are consuming these drinks; there also needs to be more general awareness amongst dental practitioners to monitor the effect of these drinks with their patients, regardless of age. As the studies show, sports drinks and their prevalence remain popular amongst the general population, therefore more research needs to be undertaken to get a more accurate understanding of this condition, especially with regards to sports drinks.[6,14]

The sample sizes of the studies were all quite small, which can affect the validity of the results, but on the plus side it was good to see ethical approval had largely been gained across the selection of the papers which increases the overall validity.

There could have been more structure in the way that the studies were organised; there were many questionnaires and face to face interviews which can be a rich source of qualitative information, but one needs to be mindful of the biases associated which can affect the validity. Other methods could have included asking them what refreshments they bring, meeting them before a training session to assess what drinks they have, or observing the athletes during a training session or pre/ post event.

More research does need to be undertaken in order to get a more accurate idea of what causes dental erosion. If these drinks do have erosive potential, or play a part in causing erosion, then it could be asked for what reasons are there no mention of the drinks having cariogenic potential, or playing a part in causing caries.

It is this reason also that would ask one question all of the studies: the main aims were for studying the prevalence of erosion or erosive potential, however, at some point in the studies there should have been mention of the other effects that these drinks cause on dental health, the most obvious one being caries.

It would seem therefore from this evidence that sports drinks do not have a significant effect on dental health. It is possible that the ingredients of the drinks tested, being a combination of both flat and carbonated, balanced each other out, thereby reducing any harmful impact. One would assume that the choice between flat or carbonated would have made a difference as it is just as easy to assume that carbonated drinks such as Coca-Cola have a negative impact on dental health, including the incidence of caries. This highlights that the evidence suggests regardless of flat or carbonated, it is largely that sports drinks do not create a negative impact on dental health, but possibly play a part in being a contributing factor to erosion though not the primary reason. Initially, it was the overall impact that sports drinks create on dental health which was the primary aim, however, once reviewing the evidence, it raises questions such as - do sports drinks not affect caries incidence, and if not, why not?

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Further resources

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DOI: 10.1038/s41407-019-0127-1