

**Title:** Consumption of energy drinks by children and young people: a rapid review examining evidence of physical effects and consumer attitudes

**Authors:** Shelina Visram, lecturer<sup>1,2</sup>  
Mandy Cheetham, postdoctoral research associate<sup>3</sup>  
Deborah M Riby, senior lecturer<sup>4</sup>  
Stephen J Crossley, research associate<sup>1</sup>  
Amelia A Lake, lecturer<sup>1,2</sup>

**Affiliations:**

<sup>1</sup> Lecturer, School of Medicine, Pharmacy and Health, Durham University Queen's Campus, Stockton-on-Tees, TS17 6BH, UK

<sup>2</sup> Fuse (UKCRC Centre for Translational Research in Public Health), Newcastle University, Newcastle-upon-Tyne, NE2 4AX, UK

<sup>3</sup> School of Health and Social Care, Teesside University, Middlesbrough, TS1 3BA, UK

<sup>4</sup> Department of Psychology, Durham University, Durham, DH1 3LE, UK

**Contact details:**

**Address:** Dr Shelina Visram, Wolfson Building, Durham University Queen's Campus, Stockton-on-Tees, TS17 6BH, UK

**Email:** [shelina.visram@durham.ac.uk](mailto:shelina.visram@durham.ac.uk)

**Telephone:** +44 (0)191 334 0061

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## **ABSTRACT**

**Objective:** To examine patterns of energy drink consumption by children and young people, attitudes towards these drinks, and any associations with health or other outcomes.

**Design:** Rapid evidence assessment and narrative synthesis.

**Data sources:** Nine electronic bibliographic databases, reference lists of relevant studies and searches of the internet.

**Results:** A total of 263 studies were located, with 38 meeting the inclusion criteria. The majority employed a cross-sectional design, involved subjects aged 11 to 18 years, and were conducted in North America or Europe. Two experimental studies involving small numbers of junior athletes demonstrated a positive impact on aspects of sports performance. Several large-scale surveys identified a strong association between consumption of energy drinks by children and young people and higher rates of smoking, alcohol and substance use, as well as physical health complaints such as headaches, stomach aches, hyperactivity and insomnia. There was some evidence of a dose-response effect. Use was found to be patterned by gender, with boys consuming more than girls, and also by activity levels, with the highest consumption observed in the most and least sedentary individuals. Three themes emerged from the qualitative studies: reasons for use; influences on use; and perceived efficacy and impact. Taste and energy-seeking were identified as key drivers, and branding and marketing were highlighted as major influences on young people's consumption choices. Awareness of possible negative effects was low.

**Conclusions:** There is growing evidence that consumption of energy drinks is associated with a range of adverse outcomes and risk behaviours in terms of children's health and wellbeing. However, taste, brand loyalty and perceived positive effects combine to ensure their popularity with young consumers. More research is needed to explore the short- and long-term impacts in all spheres, including health, behaviour and education.

**Systematic review registration:** PROSPERO 2014: CRD42014010192

## **ARTICLE SUMMARY**

### **Strengths and limitations of this study**

- This is the first independent review of the scientific literature relating to the consumption of energy drinks by children and young people
- Key strengths include the comprehensiveness of the searches, the systematic study selection process and rigorous synthesis methods used
- The inclusion of qualitative research exploring children and young people's views, alongside quantitative studies on health and other effects, helps to enhance the relevance of the findings for the design and evaluation of future policy and practice interventions
- The strength of the conclusions is limited by the quality of the individual studies, which varied widely due to factors such as the sample sizes and reliance on self-report data
- Few studies examined educational or social outcomes, highlighting a need for further research that examines the short- and long-term impact of energy drinks in relation to a wider range of outcomes

## **Introduction**

Energy drinks are non-alcoholic beverages that typically contain high levels of caffeine and sugar in combination with other ingredients known to have stimulant properties. They are marketed explicitly as a way to relieve fatigue and improve mental alertness. Between 2006 and 2013 consumption of energy drinks in the UK increased by 113%, from 235 to 500 million litres.<sup>1</sup> This equated to a per capita consumption of 7.9 litres and a total value of £1.4 billion. Despite the growing energy drinks market and media reports of serious adverse events associated with their consumption, research into their use and effects has been sparse. In 2011, the European Food Safety Authority (EFSA) commissioned a study to gather consumption data for energy drinks in 16 countries of the European Union.<sup>2</sup> They found that young people aged 10 to 18 years had the highest reported consumption prevalence (68%), compared with adults over 18 years (30%) and children under 10 years (18%). On average, young people in the UK were found to consume more energy drinks than their counterparts in other EU countries (3.1 litres per month in comparison with 2.1 litres).

The scientific literature focuses largely on the effects of energy drink consumption in adults, who may experience temporary benefits such as increased cognitive performance, enhanced mood, more physical energy, and promotion of wakefulness.<sup>3-6</sup> However, evidence is emerging on the harmful physiological and psychological effects of these drinks, and it is possible that prolonged use may affect physical and mental wellbeing.<sup>7</sup> With children and young people, anecdotal evidence suggests that those who regularly consume energy drinks can become dependent on them and even moderate consumption may be detrimental.<sup>8-10</sup> Based on the known effects of caffeine, consumption of energy drinks may lead to: caffeine intoxication and withdrawal; sleep disruption and insomnia; and disruptive, hyperactive and risky behaviour.<sup>11-13</sup> There are also likely to be health implications associated with excessive sugar intake, such as dental erosion, obesity and type 2 diabetes.<sup>14-17</sup>

Based on the importance and impact of energy drink consumption outlined above, the objectives of this study were to review the existing literature in order to: i) examine evidence of any associations between children and young people's consumption of energy drinks and their health and wellbeing, social, behavioural or educational outcomes; ii) determine whether the magnitude and direction of these associations vary according to the quantity or frequency of energy drinks consumed; and iii) explore children and young people's attitudes towards energy drinks and, in particular, what factors motivate them to consume or to abstain from consuming these drinks.

## **Methods**

We undertook a time-limited review of the literature following the guidance on rapid evidence assessments (REAs).<sup>18</sup> REAs aim to be rigorous and explicit in method, but make concessions to breadth or depth by limiting particular aspects of the review process; for example, less exhaustive use of 'grey' sources and a preference for electronically available texts.

### ***Search methods***

Searches of the following major bibliographic databases were undertaken: ASSIA, CINAHL, Cochrane Library, DARE, EMBASE, ERIC, MEDLINE, PsycINFO and Web of Science. We also conducted searches

of OpenGrey and the internet using Google to locate grey literature. Specific search strategies were employed for each database. See box 1 for lists of the key terms used. The results of each search were exported to an independent database using EndNote 7 software. These databases were subsequently merged into a single unique database and duplicates were automatically removed.

INSERT BOX 1 HERE

We adopted a broad and inclusive approach to locating original and review articles published between 2000 and 2014 that examined the consumption of energy drinks by children and young people aged 0 to 18 years (or 19 years if still in secondary education). This period was chosen to reflect the time when major brands became widely available; for example, Red Bull was introduced in the US in 1997 and Monster was created in 2002. The inclusion of studies was not restricted according to outcome type or study setting, although we excluded studies that only involved college or university students. Animal studies, articles not published in English and studies focusing on individual ingredients (e.g. caffeine or taurine) rather than energy drinks as a whole were excluded. We also excluded opinion pieces, editorials and descriptive studies without empirical findings.

### ***Study selection***

Titles of studies identified from the searches were scanned by two researchers to make an initial assessment of relevance. In cases where there was any doubt, abstracts were retrieved in order to make a further judgement. We obtained the full text of all references included after the title/abstract screening stage and PDF files were added to the bibliographic database. Articles deemed potentially relevant were reviewed independently by two researchers based on the inclusion criteria. Any disagreements were resolved by discussion between the researchers, with referral to a third member of the team where necessary. Information regarding the eligibility of a reference – relevant or not relevant – was recorded in the database to monitor the screening process. The process is summarised in the study selection flowchart (figure 1).

INSERT FIGURE 1 HERE

### ***Quality assessment***

Formal appraisal of eligible studies was undertaken using the Quality Assessment Tool for Quantitative Studies developed by the Effective Public Health Practice Project (EPHPP) and the Critical Appraisal Skills Programme (CASP) checklist for qualitative studies.<sup>19,20</sup> Both checklists have been widely used in previous systematic reviews and allow for rapid evaluation of study quality. Each paper was independently appraised by two researchers and any disagreements were resolved through discussion to reach an overall judgement concerning the quality of the available evidence (strong, moderate or weak).

### ***Data extraction***

Eligible studies were divided between members of the research team. Data were then extracted onto a template by the lead researcher for each study. Variables to be extracted included: bibliographic information; country of origin; study setting; methods; participant characteristics;

outcomes; time frame; and results of the critical appraisal. This information was stored in a Microsoft Access database. As the object was to explore all possible health, behavioural, educational and social impacts of energy drink consumption, data were extracted on any outcomes and measures used in the studies.

### ***Data synthesis***

A quantitative synthesis proved to be inappropriate due to the heterogeneity of study designs, contexts and outcomes. Data from all studies that met the inclusion and quality criteria have therefore been descriptively summarised and narratively synthesised. Narrative synthesis relies primarily on the use of text rather than statistics to 'tell the story' of the findings from the included studies.<sup>21</sup> This method is often used to increase the chances of the findings of a review being used in policy and practice. In the present review, the main narratives concerned the reported effects of energy drink consumption and the experiences and attitudes of young consumers, clearly related to the stated objectives.

## **Results**

### ***Study characteristics and quality***

Thirty-two quantitative studies, four qualitative or mixed method studies, and two literature reviews met our inclusion criteria. The quantitative studies included 24 cross-sectional surveys, five papers reporting retrospective analyses of national or regional poison centre data, and three experimental studies (tables 1-3). Most (n=30) explored the use of energy drinks by young people aged between 11 and 18 years. A small proportion of studies included children aged 10 and under either as survey respondents or in analyses of population data. Studies were largely conducted in North America (n=18) or Europe (n=11), yet all of the qualitative studies were from Australia or New Zealand (table 4). Other study contexts included the Middle East (n=3) and South America (n=1). Seventeen primary studies were rated as strong, 11 as moderate and eight as weak, although most of those rated as weak were lacking detail by virtue of being published abstracts or presentations. These have been included to provide a comprehensive overview of the current state of evidence.

INSERT TABLES 1-4 HERE

The two previous reviews were judged to be of insufficient quality to provide reliable evidence on the impact of energy drink consumption on children and young people. However, they represent important sources of expert and media opinion on this issue. The publication prepared by the American Academy of Pediatrics Committee on Nutrition and the Council on Sports Medicine Fitness set out to define the ingredients of sports drinks and energy drinks, and discuss their misuses and abuses, through a review of the literature.<sup>11</sup> This was supplemented by an analysis of position statements from the American Dietetic Association and American College of Sports Medicine, a report on school health from the Institute of Medicine, and comments solicited from committees, sections and councils of the American Academy of Pediatrics. The second review included a high proportion of reports from government agencies, interest groups and popular media, largely from the US.<sup>12</sup> Furthermore, it included animal studies and human studies involving young adults, making it difficult to extract findings relating specifically to children and young people.

### ***Effects of energy drink consumption***

Of the three experimental studies identified through the review, two measured the effects of a commercially available energy drink on aspects of sports performance in junior athletes. Pre-exercise ingestion of an energy drink significantly improved handgrip force, running pace at high intensity and number of sprints during a simulated match among tennis players,<sup>22</sup> and enhanced jump performance, mean leg muscle power output, perception of muscle power and perceived endurance among basketball players.<sup>23</sup> However, it did not have any influence on mean running pace, peak running speed or ball velocity in the first study, or the precision of basketball shots, number of free throws per second or distances covered by the players in the second study. During the simulated tennis match, sweat rate was slightly higher in the experimental group, producing significantly higher dehydration ( $p < 0.05$ ).<sup>22</sup> The third trial measured the effects of overall caffeine consumption and found that high caffeine consumers were significantly more likely to drink energy drinks ( $p < 0.001$ ).<sup>24</sup> Boys were more likely than girls to report consuming energy drinks ( $p < 0.04$ ).

Cross-sectional survey data also suggest that use of energy drinks is patterned by gender, with several studies indicating that boys are more likely to report consumption than girls, and in greater quantities.<sup>25-33</sup> Larson et al<sup>29</sup> found a significant association between regular consumption and lower frequency of breakfast for girls only, while Ludden and Wolfson<sup>33</sup> found that girls were more likely than boys to report expectations around appetite suppression. Patterns of use according to age were less clear-cut, with some surveys showing that levels of consumption increased with age<sup>28,34</sup> and others demonstrating that the converse was true.<sup>25,35</sup> Higher consumption levels were positively associated with higher socioeconomic status, lower parental education, being Black or Hispanic, and children having \$40 or more weekly spending money.<sup>30,32,35,36</sup> Al-Hazzaa et al<sup>37</sup> found that energy drink use was associated both with increased sedentary behaviour and with higher levels of physical activity. This finding was reinforced by Larson et al<sup>29</sup> and Park et al<sup>36</sup>, who found that energy drink use was correlated with hours spent watching TV or playing video games, and Azagba et al<sup>35</sup>, who found that consumption was more likely amongst young people who participated in team sports, suggesting a link with diverse leisure activities. The main health-related behaviours associated with energy drink consumption were use of alcohol and/or binge drinking, smoking or susceptibility to smoking, and substance use.<sup>26,29,30,32,34,38-41</sup> Consumption has also been linked to sensation-seeking, depression, problems with behavioural regulation and meta-cognitive skills, medical treatment for an injury and absence from school, particularly amongst frequent users.<sup>25,35,36,40</sup>

Using a representative sample of Finns aged 12 to 18 years, Huhtinen et al<sup>27</sup> found that daily use of energy drinks was strongly associated with four health complaints: headache, sleeping problems, irritation and tiredness/fatigue. Those who used energy drinks several times a day were 4.5 times as likely to experience headaches and 3.5 times as likely to experience sleeping problems, in comparison with those who did not consume these drinks. A similar survey of 10 to 12-year-olds in Iceland found that prevalence of physical complaints such as headaches, stomach aches and sleeping problems generally increased with greater energy drink use for boys and girls, although the frequency of these symptoms was less common among boys on all occasions ( $p < 0.001$ ).<sup>42</sup> The link between adverse health outcomes and ingestion of energy drinks is supported by routinely collected poison centre data from Australia, Italy and the US.<sup>43-45</sup> However, these are based on self-report data and the numbers are relatively small. For example, 62 children (mean age 36 months) who had

accidentally ingested energy drinks were reported to the New South Wales Poisons Information Centre between 2004 and 2010.<sup>44</sup> Fourteen had symptoms probably related to energy drink consumption – most commonly hyperactivity – and nine required assessment in hospital. In the US, 4854 calls (0.2%) received by the National Poison Data System in 2010-11 were for energy drink exposure cases.<sup>43</sup> Almost half (46%) were under six years old but older children reported the largest proportion of moderate or major effects, such as cardiac rhythm disturbances, hypertension and hyperthermia.

### ***Attitudes towards energy drink consumption***

Three major themes emerged through our analysis of the four qualitative or mixed method studies: reasons for use; influences on use; and perceived efficacy and impact. Taste was consistently reported as the primary driver motivating the purchase and consumption of energy drinks, with energy-seeking emerging as an important but secondary driver.<sup>46-49</sup> Participants involved in sports, particularly boys, reported using energy drinks as stimulants to enhance their sports performance. Others described using energy drinks as an alternative to soft drinks but only when they had enough money, as they were reported to be more expensive. Typical responses included: *“Wakes you up, makes you feel alert and it tastes nice”*; *“It makes me go hyper”*; and *“I drink it before soccer and I don’t lose energy as fast”*.<sup>49</sup> Jones et al<sup>48</sup> explored perceptions of alcohol-energy drinks (AEDs) among 12 to 17-year-olds and suggested that young people liked them because they increased the *“fun”* at parties and acted as a *“pick me up”*. They also found that the packaging of AEDs (to look like soft drinks) was a factor, particularly for younger teenagers and girls.

Advertising and brand loyalty emerged as major influences on young people’s use of energy drinks, with participants reporting seeing them advertised on TV, the internet, through games promotions, via sports sponsorship and in shops. In a focus group study involving three age groups (16-21, 22-28 and 29-35 years), industry marketing was seen to target specific drinks at males or females, using sexualised imagery and humour.<sup>46</sup> Participants in the youngest age group appeared to be more conscious than those in the older groups of the social image they were portraying in their choices, as well as being more sensitive to peer influences when making purchasing decisions. Social situations – and spending time with friends – provided a common context for energy drink consumption across the studies. Parents also played a key role in influencing participants’ use of energy drinks, either by disapproving or encouraging and endorsing their use.<sup>47</sup> It was generally agreed that energy drinks were easily accessible, from convenience stores or supermarkets, provided by parents, shared by siblings or friends, or obtained free at sponsored events.

Energy drinks were perceived to confer various beneficial effects on young people’s bodies and their sports performance. Participants in one study described short-term health benefits, prevention of illness, improved immunity, and a desire to rectify a poor diet.<sup>49</sup> Others described scenarios where adults used energy drinks to effectively alleviate tiredness related to work, travel or family commitments, leading Costa et al<sup>47</sup> to suggest that these drinks were ‘normalised and perceived as necessary to meet the demands of a busy lifestyle’ (p.187). Few participants across the four studies raised any negative or harmful effects, suggesting young people were either unaware of, or chose to ignore, the possible risks. Negative consequences associated with using AEDs were perceived to relate to the inclusion of a stimulant and depressant in one drink, and difficulties sleeping after



consumption.<sup>48</sup> In the study by Bunting et al<sup>46</sup>, more negative connotations became apparent in the older, adult age groups (22-28 and 29-35 years), who displayed greater scepticism as to whether energy drinks were safe. However, concerns regarding sugar content emerged across all groups and moderation was stressed due to the perceived risks of over-consumption, as opposed to general consumption of energy drinks. The youngest age group (16-21 years) believed these drinks were safe as they would not be on sale if caffeine levels were too high. Findings from other studies highlight limited knowledge of the ingredients of energy drinks, particularly among younger participants.<sup>47,48</sup>

## **Discussion**

### ***Summary of principal findings***

This review set out to examine evidence of any associations between children and young people's health and wellbeing, social, behavioural and educational outcomes, and their consumption of energy drinks. It also sought to explore consumer experiences and attitudes towards these drinks.

The evidence demonstrates that use of energy drinks by children and young people is associated with a number of adverse outcomes and risky behaviours. A total of 263 studies were located, with 38 meeting our inclusion criteria. Two RCTs demonstrated that pre-exercise ingestion of an energy drink had a positive impact on some aspects of sports performance. However, both studies involved small numbers of elite junior athletes and the results should therefore be treated with some caution. Several cross-sectional studies indicated that energy drink use by children and young people was strongly associated with higher rates of smoking, alcohol and substance use, as well as being linked to physical health complaints such as headaches, stomach aches, hyperactivity and insomnia. Two studies provided some evidence of a dose-response effect, although none of the studies was able to determine causality. Use was found to be patterned by gender, with boys consuming more energy drinks than girls, and also by age, although there was some disagreement between studies on the direction of the association. Interestingly, the highest consumption levels have been observed in sedentary individuals and in physically active individuals, suggesting a link with sport as well as screen-based leisure activities. Previous qualitative studies have reported perceived beneficial effects on young people's bodies and sports performance, with little mention of any negative effects and limited knowledge of energy drink ingredients amongst participants. Taste and energy-seeking were identified as key drivers for consumption. Advertising and brand loyalty have been highlighted as major influences on young people's attitudes towards energy drinks, and peers, parents and siblings were also found to play an important role.

### ***Comparison with other studies***

This is the first comprehensive review of the scientific literature to focus exclusively on evidence relating to the consumption of energy drinks by children and young people. Previous reviews have tended to examine the benefits and risks associated with specific energy drink components, such as sugar or caffeine. These studies provide important insights but fail to account for the fact that the presence of other substances such as guarana, ginseng and taurine in variable quantities may generate uncertain interactions and exacerbate any risks.<sup>50</sup> In addition, there is an established biochemical interaction between energy drink contents and alcohol, resulting in physical and

psychological side effects and increased risk-taking behaviour.<sup>51,52</sup> The aforementioned EFSA study found that more than half of young energy drink consumers (53%) reported co-consumption with alcohol.<sup>2</sup> Qualitative studies suggest that young people use energy drinks to continue partying and drinking alcohol over a longer period, and that they may experience negative effects ranging from difficulty sleeping to being admitted to hospital.<sup>53,54</sup> Further evidence is provided by the numerous clinical case reports relating to young people receiving emergency treatment for over-consumption of energy drinks with or without alcohol in recent years (for examples, see:<sup>55-59</sup>).

Consumption of sugar-sweetened beverages by children and young people has been shown to result in greater weight gain, increased body mass index and higher incidence of type 2 diabetes.<sup>17,60</sup> A review on the suitability of caffeinated drinks for children found that high caffeine intakes (>5mg per kg body weight per day) were associated with an increased risk of anxiety and withdrawal symptoms.<sup>61</sup> However, evidence from adult studies and expert panels was used to suggest that relatively small amounts of caffeine may benefit cognitive function and sports performance, as well as contributing to daily fluid intakes. The author was a paid member of the Tea Advisory Panel and the work was funded by the UK Tea Council. Several other studies located through our review were funded by the soft drinks industry or conducted by researchers with acknowledged conflicts of interest. The two previous independent reviews on energy drinks highlight a number of implications for children's health and wellbeing, although they also draw on expert opinion and adult studies.<sup>11,12</sup> The report by the Committee on Nutrition and the Council on Sports Medicine and Fitness in the US raises concerns about the unintentional (through the use of energy drinks for rehydration) and intentional (through the use of energy drinks to combat fatigue) ingestion of potentially large amounts of caffeine and other stimulant substances. They suggest that paediatricians have a role to play in educating children and parents on the differences between sports and energy drinks, and to counsel that routine ingestion of sugar-sweetened beverages should be avoided or restricted.

### ***Strengths and limitations of the study***

The strengths of our review include the comprehensiveness of our searches, the systematic study selection process and rigorous synthesis methods used. The review was undertaken by a multidisciplinary team of independent academic researchers. The inclusion of qualitative research exploring children and young people's views on energy drinks, alongside quantitative studies on health and other effects associated with their consumption, helps to enhance the relevance of the findings for the design and evaluation of future policy and practice interventions.

As with any literature review, the strength of our conclusions is limited by the quality of the individual studies, which varied widely. The small sample sizes in the experimental and retrospective studies, reliance on self-report data in many of the observational studies, and small number of qualitative studies located are all limitations of the review. We included a small number of published abstracts and presentations that were assessed as being weak in order to provide a comprehensive overview of the existing evidence base. Very few of the included studies examined educational or social outcomes, highlighting a need for further research that examines the short- and long-term impact of energy drinks in relation to a wider range of outcomes. Almost half of the studies were conducted in the USA and most involved high school students rather than younger children. A major gap is the lack of research conducted in a UK context. Due to time and resource constraints, we

excluded non-English language publications and may not have identified all unpublished studies. We are aware of two relevant studies published since the searches for this review were carried out: a trial demonstrating that ingestion of a caffeinated energy drink improved performance in elite junior badminton players;<sup>62</sup> and a cross-sectional study indicating that middle school students who consumed energy drinks were more likely to be at risk for hyperactivity/inattention.<sup>63</sup> These studies appear to be robust and should be considered in any update.

### ***Conclusion and policy implications***

This review adds to the growing evidence base on the health effects associated with energy drink consumption and suggests that there may be more negative than positive implications for children and young people. However, factors such as taste, brand loyalty and perceived beneficial effects help to enhance their popularity amongst young consumers. Consideration of the patterns and reasons for energy drink consumption identified in this review may help future interventions to ensure appropriate behaviours are targeted and are relevant to the population. Gender was identified as an important factor, in combination with industry marketing and perceived links to sports performance. The challenge for policies and interventions that seek to address this issue is to recognise the complexities of children and young people's consumption choices. Although health education targeting individuals is unlikely to achieve a substantial impact, definitive information about the safety of energy drink consumption should be provided by health care and other professionals. More research is needed to explore the longer-term health impacts, given that childhood and adolescence are critical yet understudied periods in the development of health-related behaviours. The potential effects of heavy and long-term energy drink consumption on child development, behaviour and educational outcomes also warrant further study.

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**Data sharing:** No additional data available

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## Tables and figures

### Box 1: Search terms

**List one: topic**

“Energy drink” OR “stimulant drink” OR “energy shot” OR “energy strip” OR “energy mint”

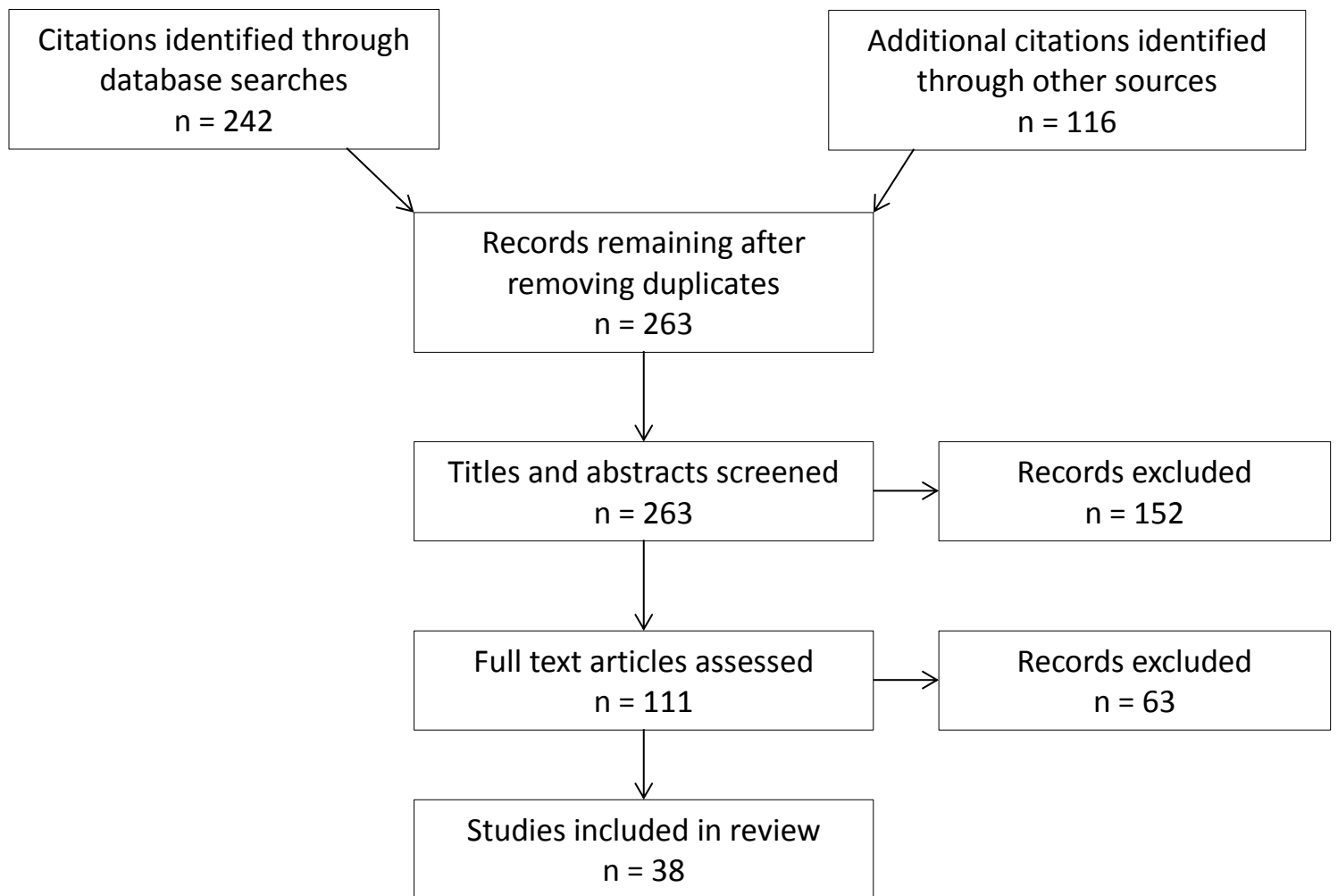
**List two: population**

Child\* OR adolesc\* OR teen\* OR (young AND (person OR people)) OR youth

**List three: outcomes**

“Health effect” OR “adverse effect” OR “positive effect” OR wellbeing OR “physical energy” OR wakeful\* OR alert\* OR “mental boost” OR performance OR sleep OR insomnia OR mood OR depress\* OR anxi\* OR (caffeine AND (intoxication OR withdrawal)) OR dehydrat\* OR headache OR nausea OR pain OR stress OR weight OR BMI OR “body mass index” OR “metabolic rate” OR “blood sugar” OR “blood pressure” OR “heart rate” OR cardiovascular OR (dental AND (health OR erosion OR caries)) OR ((disruptive OR risky OR hazardous OR anti-social OR criminal) AND behavio\*) OR ADHD OR ADD OR “attention hyperactivity deficit disorder” OR drug OR alcohol OR smok\* OR “screen time” OR “physical activity” OR exercise OR sport OR sedentary OR sex OR “self-harm” OR violence OR injury OR sociability OR “peer effects” OR learning OR memory OR attention OR attainment OR achievement OR ((absence OR exclusion) NEAR school)

**Figure 1: Study selection flowchart**



**Table 1: Experimental studies**

Study	Subjects	Study design	Intervention and dose	Outcome measures	Main findings
Abian-Vicen et al (2014)	Boys (n= 16)  Mean 14.9 +/- 0.8 years  Spain	Double-blind, placebo-controlled experimental design with repeated measures	A commercially available ED (dose: 3mg caffeine per kg body weight)	Jump performance, power, endurance and shot precision in highly skilled basketball players	Significant increases in: jump height, mean leg muscle power output, perceived muscle power, endurance and vigour during the hours following the test  Decreased rate of perceived exhaustion  No difference in: precision of basketball shots, total number of free throws per second or distances covered
Gallo-Salazar et al (2015)	Boys and girls (n=14)  Mean 16 +/- 1 year  Spain	Double-blind, placebo-controlled experimental design with repeated measures	A commercially available ED (dose: 3mg caffeine per kg body weight)	Physical performance in elite junior tennis players	Significant increases in: handgrip force, running pace at high intensity, and number of sprints during a simulated match  No difference in: peak running speed; ball velocity during the serving test  Sweat rate during the simulated match was slightly increased, producing significantly higher dehydration
Temple et al (2010)	Boys and girls (n=52)  12-17 years  USA	Double blind, placebo-controlled experimental design	Drinks containing 0 mg, 50 mg, 100 mg or 200 mg of caffeine	Cardiovascular and subjective responses to caffeine and snack food ingestion	Dose-dependent increases in diastolic blood pressure (DBP) and decreases in HR  In boys, high-caffeine consumers showed greater increases in DBP over time than did low-consuming boys  High--caffeine consumers had more energy, protein and fat in their typical diet

**Table 2: Retrospective studies**

Study	Subjects	Study design	Outcome measures	Main findings
Gunja and Brown (2012)	Boys and girls (n=62)  All ages  Australia	Retrospective review of NSW Poisons Information Centre data (Jan 2004 – Dec 2010)	Calls relating to caffeinated ED ingestion	62 children were reported to have accidentally ingested EDs (mean age 36 months, range 7-120 months)  14 had symptoms probably related to EDs (most commonly hyperactivity) and 9 required hospital assessment
Hernandez, Villarreal & Fernandez (2009)	Boys and girls (n=428)  All ages  USA	Retrospective statistical analysis of Texas regional poison centres data	Calls relating to ED ingestion, negative health consequences	The largest affected group was teenagers (n=114, compared to 84 cases <5 years)  Significant increases were noted between 2000 and 2001 (+100%); 2003-2004 (+87.5%) and 2005-2006 (+85%)  Major complaints were: rapid heart rate, nervousness/agitation, nausea, vomiting, upset stomach, dizziness, tremors, chest discomfort and headache
Seifert et al (2011)	Boys and girls (n= 1568)  All ages  USA	Retrospective analysis of US National Poison Data System	Exposure to EDs, adverse health events (toxicity)	Single product, caffeine-containing exposures disproportionately involved those aged <20 years (particularly males) compared with other substance exposures  Age groups in this category were: 47% children <6 years, 13% 6-12 years, 19% 13-19 years, 12% 20-25 years, 9% >25 years  13-19 year olds had the highest proportion of moderate or major effects (19%); the latter included cardiac disturbances, hypertension and hyperthermia
Seifert et al (2013)	Boys and girls (n=4854)  All ages  USA	Retrospective analysis of US National Poison Data System	ED use and ED-related toxicities	Of the 4854 calls relating to ED exposure, 3192 cases were categorised as 'unknown', 1480 were non-alcoholic and 182 alcoholic  Children <6 had the highest proportion of unintentional exposures to non-alcoholic ED; minor or moderate adverse effects were reported  Adolescents (13-19) had the highest proportions of intentional exposures and the largest proportion of cases of minor to moderate effects, with one major effect  For alcoholic ED, 54.3% ingestions were 13-19 years, 4.1% 6-12 years and 9.8% <6 years; a greater proportion of alcoholic ED cases were advised to seek treatment
Vecchio et al (2013)	Boys (n= 24)	Retrospective analysis of Pavia Poison	Use / abuse of EDs, voluntary / accidental, any	Of those aged under 18, all were male and all had consumed Red Bull (0.5-2 cans, where known)

	<p>All ages (mean 26.5 years)</p> <p>Italy</p>	Control Center data	co-assumed substance, clinical picture	<p>Four had co-ingested with alcohol, plus other substances in two of these cases</p> <p>Symptoms: malaise, palpitations, fainting , abdominal/gastric pain, agitation, flushing, tachycardia, motor incoordination, confusion, hallucinations, delirium, vomiting, drowsiness, mydriasis (dilation of the pupil), tremors</p>
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**Table 3: Cross-sectional studies**

Study	Subjects	Study design	Outcome measures	Main findings
Al-Hazzaa et al (2013)	Boys and girls (n=2908)  15-19 years	Multicentre cross-sectional study	Weight, height, BMI, total daily screen time (ST), physical activity (PA) and dietary habits (DH) using self-report questionnaires	Significant associations of higher consumption of EDs with both higher PA levels and higher ST  PA did not correlate with consumption of sugar-sweetened drinks overall but did associate significantly with intake of EDs  Insignificant associations between PA and intake of EDs in females
Aluqmany et al (2013)	Girls (n=600)  15-18 years (mean 17 years, SD 0.98 years)  Saudi Arabia	Cross-sectional secondary school based survey	Knowledge of ED and effects, reasons for consumption, personal consumption	55.5% prevalence of ED consumption, although 45.0% used them irregularly  Most had close friends who consumed EDs; current consumption was correlated with consumption by a family member or friend  69.6% of the students did not know the active ingredients of energy drinks  35.0% attributed their popularity to advertising, 25.6% used EDs to increase vitality and 20.8% used them to be alert  27.5% had tried stopping use, and 34.9% of them had had withdrawal symptoms
Azagba et al (2013)	Boys and girls (n=36,155)  12-18 years  Canada	Cross-sectional, classroom-based, biennial Youth Smoking Survey	Consumption, mixed or premixed with alcohol during the past 12 months	About 20% reported using alcohol mixed with EDs in the last year; prevalence of use was highest among Aboriginal (33.8%) and black (25%) students  Students who were older; currently smoked; were involved in heavy drinking in the past year; used marijuana in the past year; were absent from school; participated in school team sports; and had \$40 or more weekly spending money were more likely to consume alcohol mixed with EDs in the previous year  Students who felt more connected to school and who had an academic average of 70% or higher were less likely to consume these drinks
Azagba and Sharaf (2014)	Boys and girls (n=15,875)  14-18 years  Canada	Cross-sectional, classroom-based, biennial Youth Smoking Survey	Susceptibility to smoking, consumption of alcohol mixed with ED (AmED)	About 13% of students used AmED  A statistically significant positive association was identified between consuming AmED and susceptibility to smoking among adolescent students  Never-smoking students who reported

				consuming AmED had higher odds of susceptibility to smoking
Azagba et al (2014)	Boys and girls (n=9226)  12-13 years, 14-16 years, 17-18 years	Cross-sectional, high school-based Student Drug Use Survey	ED usage	62% reported consuming EDs at least once in the previous year, with about 20% reporting use once or more per month  Sensation seeking, depression, and substance use were all higher among ED users relative to non-users, and in higher frequency users relative to lower frequency users  Males were much more likely to report ED consumption than female students  Rates of ED use were higher among younger students and the prevalence of consumption decreased with age
Champlin and Pasch (2013)	Boys and girls (n=356)  16-18 years  USA	Cross-sectional high school based survey.	ED use and reasons for use	ED use was highly prevalent, with 81.1% reporting ever consuming an ED  Among users, the most common reasons given for consumption were: it tastes good (73.7%), refreshment (59.9%), needing more energy in general (45.8%), and hydration and thirst quenching (38.1%); the least common reasons were: weight management (7.9%), health and nutrition (11.9%), and to replace a meal (13.8%)
Cotter et al (2013)	Boys and girls (n=43)  13-17 years  USA	Cross sectional computerised questionnaire with sub-critically ill or injured adolescents in paediatric emergency department	Prevalence, quantity and coingestion of alcohol, caffeinated beverages, pills, illicit drugs and tobacco use over previous 30 days and lifetime usage  Reasons for ED use	ED drink use among adolescents far exceeded that of alcohol, "street" or illicit drug and tobacco usage. Those who reported ED use had higher prevalence of street drug use than non-ED users  On a typical day adolescents drank 1.5 EDs (range, 0-7 drinks)  The most highly cited reasons for ED use were: 29.4% "to play sport better", 23.5% "to keep awake for school", 23.5% "because your friends or others were using them", 23.5% "to party", 11.8% "to lose weight" (less cited reasons: 5.9% "to not feel hungry", "to keep awake for work", "to do better at work", "to keep awake while driving")
Gallimberti et al (2013)	Boys and girls (n=913)  11-13 years  Italy	Cross-sectional school-based survey	Consumption of EDs, other substance abuse	Use of EDs increased significantly with age, from 17.8 % among sixth graders to 56.2 % among eighth graders  Among the male student population, 16.5 % of those in the eighth grade and 6.21 % of those in the sixth grade drank them at least once a week

				Independent variables conferring a higher likelihood of being at least once-a-week ED consumers were smoking and alcohol consumption. Awareness of the damage caused by EDs emerged as a protective factor that reduced the likelihood of young students consuming such drinks
Gambon et al (2011)	Boys and girls (n=502)  12-19 years  Netherlands	Cross-sectional school-based survey, single centre	Data on consumption of EDs, soft drinks, sports drinks and alcopops	39.4% used EDs (in comparison with 85.2% soft drinks, 44.7% sports drinks, 12.8% alcopops)  Boys consumed soft drinks, EDs and sports drinks more frequently than girls, and on average also consumed higher amounts of these drinks  Significant positive associations were observed between the consumption of soft drinks, EDs and/or sports drinks. Alcopop consumption was only associated with EDs  The mean consumption of soft drinks, EDs and sports drinks was highest at 14-15 years, after which it declined
Hamilton et al (2013)	Boys and girls (n=4,472)  12-19 years  Canada	Retrospective review of Ontario Student Drug Use and Health Survey	ED intake	49.6% of adolescents had consumed EDs in the previous year  Energy drink consumption in the previous year was highly associated with tobacco, cannabis and non-medicinal use of prescription drugs use in the previous year, and binge drinking in the previous month.  Consumption was also highly associated with sensation-seeking and self-reports of medical treatment for an injury (reported by 16% and 42% of adolescents)
Huhtinen, Lindfors and Rimpela (2013)	Boys and girls (n= 10,406)  12-18 years  Finland	Adolescent Health and Lifestyle Survey, postal and online survey	Association between EDs and four caffeine-induced health complaints (headache, sleeping problems, irritation, tiredness / fatigue)	44% of adolescents used EDs at least sometimes (2% of girls and 4% of boys used them daily, 0.5% several times a day)  Daily use of EDs was strongly associated with the four health complaints. In adjusted models, health complaints among those who used EDs several times a day were multi-fold compared with the non-users: headache (OR = 4.5), sleeping problems (3.5), irritation (2.4) and tiredness/fatigue (3.4).
Kristjansson et al (2014)	Boys and girls (n=11,267)  10-12 years  Iceland	Population-based primary school survey	Prevalence of caffeinated sugar-sweetened beverages (CSSBs) and the relationship	Just over 7% of boys and almost 3% of girls report consuming EDs on a daily basis  Use of CSSBs is more common among boys and physical complaints are more common among girls. About one in five girls reported having headaches, stomach aches



			with common physical complaints	and/or sleeping problems sometimes or often during previous 7 days. For boys and girls the prevalence of physical complaints generally increased with greater ED use
Kumar et al (2014)	Boys and girls (n=840)  12-17 years  USA	Online survey	ED consumption	9% reported consuming ED $\geq 1$ time/week  Significant differences were found by age and gender (increasing prevalence among older teens and in males) but not for the other characteristics examined.  Only 11.5% were ever asked by their doctor/nurse about how often they drank EDs, and 11.1% were ever recommended by their doctor/nurse to not drink EDs  The proportion of youth who consumed energy drinks $\geq 1$ time/week was higher among youth who were asked by their doctor/nurse about how often they drank energy drinks than by youth who were not
Larson et al (2014)	Boys and girls (n=2793)  Mean 14.4 years (SD 2.0 years)  USA	Cross-sectional school based survey (questionnaire plus anthropometric measures)	Sport and ED intake, PA and sport participation, media use, sleep, cigarette smoking, breakfast frequency and other beverage intake, weight status, demographics	Overall, EDs were consumed at least 1/wk by 14.7% of the sample (significantly higher among boys than girls). Differences in ED consumption by ethnicity were statistically significant only among girls  Regular ED consumption was associated with measures of media use, other beverage intake, and cigarette use, but was unrelated to measures of PA. For both genders, regular consumption was positively associated with ever having smoked cigarettes and weekly video game use  There was a significant association between regular ED consumption and higher daily intake of sugar-sweetened soft drinks and fruit drinks. For girls only, there was also a significant association with lower frequency of breakfast
Locatelli et al (2012)	Boys and girls (n=2705)  15-17 years  Brazil	Self-administered questionnaire in private high schools	Alcohol use by socioeconomic level and gender	31.6% reported having used alcohol and ED together at least once in life. Boys reported a higher prevalence of frequent alcohol use, binge drinking, and the combination of alcohol with ED  Mixing alcohol and ED was most common in students from class A1 (45.5%) and decreased gradually with socioeconomic class to 17.7% in classes D/E [high to low]
Bryant Ludden and Wolfson	Boys and girls (n=197)  14-18 years	Self-report measures completed during school	Patterns of caffeine use, linking to reasons for use,	Among those who used caffeine yesterday, 6.1% reported ED use (compared with 60.5% soda, 19.3% coffee, 4.4% tea and 8.8% other)

(2010)	USA	hours	expectancies and sleep patterns	Males drank soda and ED more frequently, although females were more likely to report withdrawal/dependence caffeine expectancies and appetite suppression expectancies
Musaiger and Zagzoog (2014)	Boys and girls (n=1,061) 12-19 years Saudi Arabia	School based short questionnaire extracted from a validated questionnaire, after modifications to include ED	Knowledge, attitudes and intake of energy drinks among adolescents	31.9% of males and 24.7% of females drank EDs 1–2 days per week, with a significant difference between the genders  Advertisements were the main single source of information on ED. The main reasons for consumption were for their taste and flavour (58.4%), in order to 'try them' (51.8%) and to 'get energy' (43%)  About half did not know the ingredients of ED and a similar proportion knew they contained caffeine. Two-thirds viewed EDs as soft drinks
Nelson et al (2008)	Boys (n=305) 14-18 years USA	School based multiple choice survey,	Rates and characteristics of ED consumption among athletes	49% used 1-10 cans in the past month, while 9% used greater than 10 cans in the past month. Among these modest and high consumers, the most usual times of ED use were: before football (39%), before school (23%), at social gatherings (22%), after football (20%), during school (14%), during football (11%) and while studying (11%).  Most popular reasons for ED use were: to increase energy (61%), enjoyment of taste (56%), thirst (33%) and increase alertness (27%). 18% believed EDs help them play better. Reported side effects were: rapid heartbeat (11%), light-headedness (9%), muscle cramping (7%) and diarrhoea (6%)
Park et al (2011)	Boys and girls (n= 11,029) 14-18 years USA	School-based survey	Demographic characteristics, weight status, availability of school vending machines, and behavioral factors with sugar-sweetened beverage (SSB) intake	Mean total ED intake was 0.2 times per day and only ~5% of students reported drinking a can, bottle or glass $\geq 1$ time per day.  Being male, non-Hispanic black, or Hispanic (vs. non-Hispanic white), eating at fast-food restaurants $\geq 3$ time per week and watching television $> 2$ hours per day were significantly associated with greater odds of drinking EDs $\geq 1$ time/d, whereas having beverage vending machines in the school was significantly associated with reduced odds of drinking EDs $\geq 1$ time/d
Petrova et al (2013)	Boys and girls (n= 4322) 6-18 years Bulgaria	Cross-sectional nutrition survey, including Food Frequency Questionnaire	Use of EDs and correlation with alcoholic drinks	Consumption of ED starts in the age 6-9 years. 50.4% of 10-18 year olds were non-consumers of ED (never consumed and consumed less than once monthly). 18.3% of 10-13 year olds and 33.5% of 14-18 year olds consumed at least one ED per week. 13.4% of boys in the 14-18 years group

				<p>ingested ED every day (7.3% more than one per day)</p> <p>Significant correlations between use of ED and consumption of spirits and beer, and co-occurrence of EDs and alcoholic drinks in older age groups, were found</p>
Santangelo et al (2013)	<p>Boys and girls (n= 1232)</p> <p>12-19 years (mean 14.8, SD 3.8)</p> <p>Italy</p>	School based self-report questionnaire	ED consumption - levels and motivating factors	<p>EDs were consumed by 30.7% of the sample; 7.1% drank ED at least 1 time/day, 32.3% 1–2 times/week and 47.3% 1–2 times/month</p> <p>90.2% consumed EDs for the flavour, 38.9% found them refreshing, 18% and 10.3% wanted to achieve an improvement in sports performance and intellectual activity, respectively. 71.4% consume EDs when outside, 28% at meals, 19.6% in front of TV/PC, 10.3% at school and 10% during or after physical exercise</p>
Terry-McElrath et al (2014)	<p>Boys and girls (n=21,995)</p> <p>13-18 years</p> <p>USA</p>	Classroom based self-completion questionnaire	ED consumption and substance use	<p>ED/shot use was higher among boys, younger students and those residing outside of metropolitan areas. There were negative relationships with two parents in the home and higher average parental education. Neither race/ethnicity nor region was associated with ED/shot use and consumption did not significantly change between 2010 and 2011</p> <p>ED/shot use frequency was significantly and positively correlated with past 30-day use frequency of all substance use measures (alcohol, cigarettes, marijuana, and amphetamines) for all grades</p>
Van Batenburg-Eddes et al (2014)	<p>Boys and girls (n= 509)</p> <p>11-16 years (mean 13.1 years, SD 0.85)</p> <p>Netherlands</p>	Cross-sectional school based survey, part of a larger longitudinal project	Executive functions, plus caffeine and ED intake	<p>6% reported consuming on average at least one ED a day. Problems with falling asleep and waking up were reported most often (23%). Consuming on average one ED or more a day was associated with problems with self-reported behaviour regulation. Participants who drank at least two consumptions of caffeine or ED also had more problems with meta-cognitive skills</p>
Vilija and Romualdas (2014)	<p>Boys and girls (n= 1747)</p> <p>12-13 years</p> <p>Lithuania</p>	Cross sectional school based study using self-administered questionnaire	Posttraumatic stress (PTS) symptoms, lifetime traumatic experiences, food frequency scale, sense of coherence scale	<p>21.0% consumed EDs on a daily basis. All lifetime traumatic events were associated with unhealthy foods (including EDs) and sense of coherence weakened the strength of the associations.</p>

**Table 4: Qualitative and mixed method studies**

Study	Subjects	Study design	Aims	Main findings
Bunting et al (2013)	Boys and girls (n= 12)  16-21 years  New Zealand	Focus groups stratified by age (16-21, 22-28 and 29-35 years)	To obtain participants' perceptions of caffeinated EDs	Themes: advertising, age, alcohol, brand, efficacy, energy-seeking, gender, health, peer influence, product attributes, and safety.  Taste appeared to be the primary driver motivating the purchase and repurchase of EDs
Costa, Hayley and Miller (2014)	Boys and girls (n= 40)  12-15 years  Australia	Focus groups	To explore perceptions, patterns, and contexts of ED use	Themes: knowledge about ED brands and content, ED use, reasons for ED use, physiological effects, and influences on ED use  Participants were familiar with a range of EDs and most had used them at least once, but had limited knowledge of ED ingredients and could not easily differentiate them from other drink types.
Jones (2011)	Boys and girls (n=95)  12-14 years 15-17 years  Australia	Focus groups (separate by age and gender), supplemented with school and online survey data	To explore perceptions and consumption of alcohol EDs (AEDs)	Many participants commenting that they had consumed AEDs, or seen others consuming them. Findings suggest they may be particularly popular among young females  Drinking in the 15-17 age group took place predominantly at parties and friends' houses, as well as at family gatherings  Only a small number of survey respondents raised negative consequences of consuming AEDs
O'Dea (2003)	Boys and girls (n= 78)  11-18 years  Australia	Focus groups	To explore the type of nutritional supplements and drinks consumed by adolescents, along with reasons for consumption	In the 2 weeks prior to the focus groups, 42.3% of participants had consumed EDs (compared with 54.6% who consumed sports drinks)  Reasons for consumption of EDs: energy, taste, sports performance, soft drink substitute, peer group pressure, attractive packaging.