

# BMJ Open Consumption and effects of caffeinated energy drinks in young people: an overview of systematic reviews and secondary analysis of UK data to inform policy

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## ABSTRACT

**Background** This overview and analysis of UK datasets was commissioned by the UK government to address concerns about children's consumption of caffeinated energy drinks and their effects on health and behaviour.

**Methods** We searched nine databases for systematic reviews, published between 2013 and July 2021, in English, assessing caffeinated energy drink consumption by people under 18 years old (children). Two reviewers rated or checked risk of bias using AMSTAR2, and extracted and synthesised findings. We searched the UK Data Service for country-representative datasets, reporting children's energy-drink consumption, and conducted bivariate or latent class analyses.

**Results** For the overview, we included 15 systematic reviews; six reported drinking prevalence and 14 reported associations between drinking and health or behaviour. AMSTAR2 ratings were low or critically low. Worldwide, across reviews, from 13% to 67% of children had consumed energy drinks in the past year. Only two of the 74 studies in the reviews were UK-based. For the dataset analysis, we identified and included five UK cross-sectional datasets, and found that 3% to 32% of children, across UK countries, consumed energy drinks weekly, with no difference by ethnicity. Frequent drinking (5 or more days per week) was associated with low psychological, physical, educational and overall well-being. Evidence from reviews and datasets suggested that boys drank more than girls, and drinking was associated with more headaches, sleep problems, alcohol use, smoking, irritability, and school exclusion. GRADE (Grading of Recommendations, Assessment, Development and Evaluation) assessment suggests that the evidence is weak.

**Conclusions** Weak evidence suggests that up to a third of children in the UK consume caffeinated energy drinks weekly; and drinking 5 or more days per week is associated with some health and behaviour problems. Most of the evidence is from surveys, making it impossible to distinguish cause from effect. Randomised controlled trials are unlikely to be ethical; longitudinal studies could provide stronger evidence.

## Strengths and limitations of this study

- The main strength of this study was the novel use of a secondary data analysis to fill a gap in the evidence that was identified by the overview.
- A strength of the overview was its robust methods, and that it only included reviews that used systematic methods.
- A limitation of the overview was the strength of evidence of the primary research, most of which was from cross-sectional surveys.
- The main limitations of the dataset analysis were that longitudinal data were not available, and the survey data could not be combined due to differences between surveys in their designs and measures reported.

**PROSPERO registrations** CRD42018096292 – no deviations. CRD42018110498 – one deviation – a latent class analysis was conducted.

## INTRODUCTION

Caffeinated energy drinks (CEDs) are drinks containing caffeine, among other ingredients, that are marketed as boosting energy, reducing tiredness, and improving concentration. They include brands such as Red Bull, Monster Energy, and Rockstar. There is widespread concern about their consumption and effects in children and adolescents (under 18 years old).<sup>1–4</sup> Some professional organisations have suggested banning sales to children.<sup>2</sup> In the UK, warnings, aimed at children and pregnant women, are required on the packaging for drinks that contain over 150 mg/L of caffeine.<sup>5</sup> An average 250 mL energy drink contains a similar amount of caffeine to a 60 mL espresso, and the European Food Safety Authority proposes a safe level of 3 mg

of caffeine per kg of body weight per day for children and adolescents.<sup>6</sup> Many drinks also contain other potentially active ingredients, such as guarana and taurine, and more sugar than other soft drinks, although there are sugar-free options.<sup>7–9</sup> Children may be more at risk of ill effects than adults.<sup>10,11</sup> Effects could be physical (eg, headaches), psychological (eg, anxiety) or behavioural (eg, school attendance or alcohol consumption).<sup>12</sup> Available systematic reviews report a wide range of findings, including positive effects on sports performance.

In 2018, the UK government ran a consultation on implementing a ban on sales to children,<sup>13–15</sup> and in March 2019 they published a policy paper.<sup>16</sup> The research reported here was commissioned by the Department of Health and Social Care (DHSC), England, in 2018, to identify and assess the evidence on the use of CEDs by children. As the deadline was short, and as initial searches identified several systematic reviews, a systematic review of systematic reviews (referred to as overview, from this point onwards) was conducted. As only two UK studies were identified within the reviews included in the overview, UK datasets were sought, and a secondary analysis of relevant data was carried out to supplement the international literature and ensure relevance to UK policy. Full reports are available.<sup>17,18</sup>

The research questions (RQ) were:

RQ1. What is the nature and extent of CED consumption among people aged 17 years or under in the UK?

RQ2. What impact do CEDs have on young people's physical and mental health, and behaviour?

## METHODS

This paper summarises the overview and dataset analysis.<sup>17,18</sup> For the overview, a literature search was conducted during May 2018 and updated on 2 July 2021. EPPI-Reviewer software<sup>19</sup> was used to manage the data. The gaps, identified by the overview and a search for primary studies, guided the search, conducted during August 2018, for UK datasets and their subsequent analysis. STATA v13<sup>20</sup> was used to analyse the datasets. Ethical approval was granted by UCL's Ethics Committee. Protocols were registered on PROSPERO (CRD42018096292 and CRD42018110498).

### Search strategies

For the overview, we searched nine databases, focusing on research in health, psychology, science or social science, or general research. We completed forward citation searching in Google Scholar for 13 included reviews. The databases searched and the MEDLINE search strategy are in the online supplemental file (section 1). The search terms were based on three concepts: caffeine, energy drink, and systematic review. The searches were limited to the publication year of 2013 onwards, to identify the most recent systematic reviews. For the dataset analysis, search terms were based on caffeine and energy drink.

We searched the UK Data Service<sup>21</sup> (accessing over 6000 UK nation population datasets), with no restrictions.

### Inclusion criteria

For the overview:

- ▶ Systematic review published since 2013
- ▶ Extractable data on children under 18 years of age
- ▶ Available in English
- ▶ Patterns of CED use or associations with physical, mental, social or behavioural effects.

Four reviewers (GB, CK, GR and CS) screened references based on their titles and abstracts, and then screened potential includes on their full texts. The four reviewers double-screened batches of 10 references until their decisions to include or exclude each paper were the same on at least nine of the 10 (90%), then they screened individually. Disagreements and indecisions were resolved by another of the four reviewers, where necessary.

For the dataset analysis:

- ▶ Downloadable datasets, representative of the UK or a constituent country
- ▶ Information on the levels and patterns of CED consumption
- ▶ Data on children under 18 years of age (adults could provide the data on their behalf)
- ▶ Reporting primary (frequency, amount, or occurrence of drinking/not drinking (comparator)) or secondary (sugar consumption, cardiovascular health, mental health, neurological conditions, educational outcomes, substance misuse, sports performance or sleep characteristics) measures.

After a pilot batch, for which two reviewers (GB and DK) assessed datasets independently and discussed their decisions to include or exclude, the remaining datasets were screened, independently.

### Data extraction

From the systematic review reports that met the overview inclusion criteria, we extracted details on/for: systematic review methods; included studies; CED consumption; associations with physical, mental, social or behavioural effects; and risk of bias assessment. One reviewer (GB, CK, GR or CS) extracted these data, which were checked by another reviewer. For the dataset analysis, one reviewer (GB or DK) extracted dataset characteristics (sample size, etc); details on participants (age, gender, etc) and consumption (how it was measured, etc); well-being and health outcomes, including potential confounders; and information on missing data and for risk of bias assessment.

### Syntheses

The data extracted from the systematic reviews were synthesised in a narrative format due to variation between reviews. Prevalence was synthesised by the measure used, where possible. Associations were synthesised by whether they were physical, mental, behavioural, or social/educational, and summary tables were produced. One reviewer

(GB, CK, GR or CS) synthesised the data and another checked each synthesis.

Each dataset was analysed for prevalence and frequency of CED consumption, and any variations by children's characteristics. Most of the cross-sectional analyses were bivariate (exploring interactions between two features), with binary and multinomial logistic regression used to control for confounders. A latent class analysis (LCA) was conducted,<sup>22</sup> for one dataset. The latent profiles were based on children's health experiences, such as headaches, anxiety, or dizziness. The observed variables (11 indicators of child well-being) and latent variables (five classes of well-being) were identified from the data. Class membership was used as the dependent variable in multinomial logistic regressions. Descriptive associations were explored in bivariate analyses of the 11 indicators, separately. The results from individual datasets were synthesised in a narrative because meta-analysis was not deemed to be appropriate. Missing data were not imputed, as it was not possible to determine if they were missing at random. One reviewer (DK) analysed the data.

### Risk of bias

AMSTAR2<sup>23</sup> was used to assess the risk of bias in the included systematic reviews, because some reviews included randomised controlled trials (RCTs) as well as non-RCTs. AMSTAR2 has questions on the protocol, inclusion criteria, search, selection, data extraction, risk of bias assessment, reporting, synthesis (RCTs and non-RCTs), and conflicts of interest; a question on relevance was added. The strength of the evidence was assessed using GRADE (Grading of Recommendations, Assessment, Development and Evaluation) criteria,<sup>24</sup> which can be used to determine whether the evidence is strong or weak, based on any risk of bias, including in study design and size, consistency of the results, relevance to the population, and potential publication bias. Overlap, where the same primary studies appear in more than one review, was assessed.<sup>25</sup> Overlap can lead to double counting of the results of a study, giving these more influence than those of other studies.<sup>26</sup> Two reviewers (CK and GR) assessed risk of bias; random samples were checked by a third reviewer (GB). Datasets were not formally assessed, but all datasets met the quality assurance criteria of the UK Data Service.<sup>27</sup> Data on exposure (quantity, frequency and type of drink), sample frame (characteristics of participants), and level of participation (response rate) were extracted, by one reviewer (DK), to determine their parameters.<sup>17</sup> In line with National Institutes of Health guidance,<sup>28</sup> no overall risk of bias score was produced for each dataset because overall scores can be misleading where the risk of bias on each criterion has a different impact on the reliability of the conclusions.

### Patient and public involvement

We did not include young people in the research process.

## RESULTS

The overview searches identified 1102 references, after deduplication (see figure 1); 126 were screened on full texts. We included 15 reviews; six reported information on prevalence,<sup>12 29–33</sup> and 14 reported associations.<sup>12 29–32 34–42</sup> The reasons for exclusion, based on assessment of the full text, are reported in the online supplemental file (section 2). Most were excluded because they did not use systematic review methods or did not report information on children.

Three reviews focused on CEDs in children.<sup>12 30 41</sup> One<sup>35</sup> focused on children, with a section on CEDs alongside other drinks. The other 11 reported information on children alongside data for adults; one<sup>29</sup> with CEDs alongside other drinks, and two<sup>31 32</sup> focusing on alcohol mixed with CEDs. For summary and full characteristics, see the online supplemental file (section 3) and the full report.<sup>18</sup>

For the dataset analysis, as there was no facility to export results, it was not possible to record the flow of datasets through screening. Five datasets met the inclusion criteria; analyses were not possible for one dataset<sup>43</sup> (see table 1). For full descriptions, see the full report.<sup>17</sup>

### Risk of bias

There was a high risk of bias in all but three of the reviews—Visram *et al*,<sup>12</sup> and Bull *et al*.<sup>37</sup> Yasuma *et al*<sup>41</sup> (details in the online supplemental file, section 4)—meaning that some relevant evidence may have been missed. Overlap between studies in the reviews was slight (corrected covered area 3.2%; see the online supplemental file, section 5). The reviews did not include any analyses of the UK datasets that we analysed. Within the reviews, there were four small randomised controlled trials, while most studies were surveys with a high risk of bias; the application of GRADE criteria, which are used to assess the overall strength of the evidence found, suggests that the evidence is weak. Exposure, sample frame and level of participation for the datasets are reported in appendix 1 of the full report.<sup>17</sup>

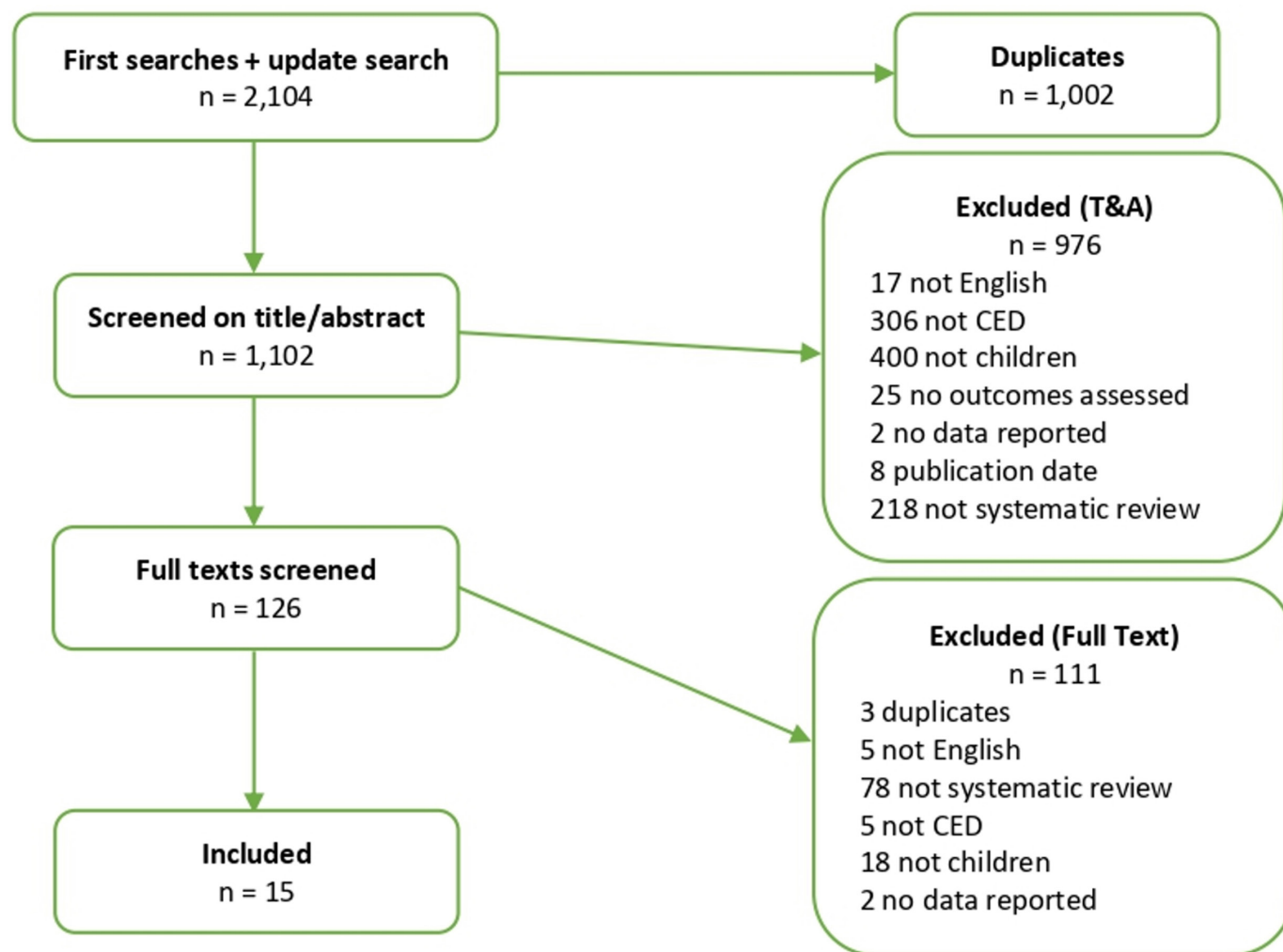
### UK studies in the overview

Of the 74 studies identified by the reviews that are summarised in the overview, two were UK surveys. One<sup>44–46</sup> was a longitudinal (two time-points) cross-sectional survey of 11- to 17-year-olds in the south-west of England. The other<sup>47</sup> was a survey of 13- to 18-year-olds across 22 European countries, one of which was the UK (2.6% of respondents).

Below and in tables 2–4, the overview results are summarised by research question, followed by highlights of the dataset analysis within each topic. The full results of the overview<sup>18</sup> and dataset analysis<sup>17</sup> are available online.

### RQ1. Nature and extent of CED consumption

The overview included six reviews with data on prevalence of children's CED consumption, and these are summarised in table 2.



**Figure 1** Flow diagram for the overview. CED, caffeinated energy drinks; T&A, title and abstract.

Across reviews, prevalence varied by study location, population age range, and definition of drinking (ever drunk, in the past year, regularly, with alcohol, etc) from 13% to 67% of children having a CED in the past year.<sup>30 32</sup> One meta-analysis<sup>29</sup> of four studies in the Gulf states suggested that about two thirds of children consumed CEDs (not further defined; 65.3%, 95% CI 41.6 to 102.3 (as reported in the paper)). Across reviews, weekly or monthly drinking ranged from 13% to 54%<sup>48</sup> of

children. In one study, across Europe, UK children had the highest proportion of caffeine intake from CEDs, at 11%,<sup>47</sup> but this might reflect a lower intake from coffee or tea. Across reviews, 10%<sup>49</sup> to 46%<sup>50</sup> of children had tried CEDs with alcohol.

In the UK dataset analysis, self-reported prevalence was relatively consistent across UK countries (see [table 3](#)), although there were differences in the questions asked. About a quarter of children aged 13 to 14 years consumed

**Table 1** Description of the five datasets included in the secondary data analysis

Dataset	Abbreviation	Region	Collection period(s)	Ages (years)
Millennium Cohort Study (longitudinal) <sup>43</sup>	MCS	UK	2008	9 months, 3, 5, 7, 11, 14, 17
Smoking and Drinking Survey of Young People† <sup>51</sup>	SDSYP	England	2014	7 to 11
Health Behaviour in School Children (Wales)† <sup>65</sup>	HBSC	Wales	2013/14 and 2017/18	11, 13 and 15
National Diet and Nutrition Survey <sup>66</sup>	NDNS	UK	2014 to 2016	1.5 to 18
Young Persons' Behaviour and Attitudes Survey <sup>67</sup>	YPBAS	N Ireland	2016	8 to 12

\*Only collected data on CED consumption at age 7 years (2008). Fewer than five parents reported that their child (out of >13 500 children) would drink CEDs between meals and the data were not used in analyses.

†Used to explore associations with hypothesised antecedents or consequences of CED consumption.  
CED, caffeinated energy drinks.



**Table 2** Characteristics and main findings of reviews reporting prevalence of consumption

Review details	Methods and study details	Main findings on prevalence, and associated characteristics (% of children)
Children or young people		
<b>Reference:</b> Visram (2016) <sup>12</sup> <b>Exposure:</b> CEDs <b>Age:</b> 10 to 20 years	<b>Included:</b> 46 studies (RCTs, surveys and qualitative) <b>Published:</b> 2003 to 2016 <b>Risk of bias tool:</b> CASP and EPHPP	Higher for boys than girls Higher for black children than white (three studies); white than black (one study) Age associated with drinking, but the direction of the association varied by study <b>UK study:</b> drinking associated with being male, older, eligible for free school meals, and having special educational needs
<b>Reference:</b> Dawodu (2017) <sup>30</sup> <b>Exposure:</b> CEDs <b>Age:</b> 10 to 18 years	<b>Included:</b> 12 surveys (4 on prevalence) <b>Published:</b> 2013 to 2015 <b>Risk of bias tool:</b> None	Higher for boys than girls In the past year – 62% or 67% Once a month or more – 20% Recent (undefined) – 13% Ever with alcohol – 10% Weekly – 15% or 16%
Children and adults (subsection on children)		
<b>Reference:</b> Alhyas (2016) <sup>29</sup> <b>Exposure:</b> CEDs <b>Age:</b> 12 to 19 years	<b>Included:</b> 5 surveys, 6138 children <b>Published:</b> 2011 to 2014 <b>Risk of bias tool:</b> None	Higher for boys than girls Boys start at 17.1 years, and girls at 16.7 years Meta-analysis: 65.3% (95% CI 41.6% to 102.3%; four studies) consumed CEDs (not further defined)
<b>Reference:</b> Roemer (2017) <sup>31</sup> <b>Exposure:</b> Alcohol mixed with CEDs <b>Age:</b> 11 to 20 years	<b>Included:</b> 3 surveys (2 prevalence) <b>Published:</b> 2014 to 2015 <b>Risk of bias tool:</b> No tool, some assessment	Higher for boys than girls (one study); no difference (one study)
<b>Reference:</b> Verster (2018) <sup>32</sup> <b>Exposure:</b> Alcohol mixed with CEDs <b>Age:</b> 14 to 19 years	<b>Included:</b> 6 surveys <b>Published:</b> 2013 to 2016 <b>Risk of bias tool:</b> None	In past year – 13% to 20% (Canada) In past month – 13% (USA) Ever consumed – 46.1% (Italy) Higher for black children than white
<b>Reference:</b> Verster and Koenig (2018) <sup>33</sup> <b>Exposure:</b> Section on CEDs <b>Age:</b> 2 to 22 years	<b>Included:</b> 8 surveys <b>Published:</b> 2002 to 2015 <b>Risk of bias tool:</b> None	Percentage of caffeine intake that is from CEDs: 11% UK; 0.6% Germany; 2–3% New Zealand; 5–6% USA; 5.3% Belgium; 6% Australia; 8.1% Netherlands

CASP, Critical Appraisal Skills Programme; CEDs, caffeinated energy drinks; EPHPP, Effective Public Healthcare Panacea Project; RCTs, randomised controlled trials.

one drink or more per week (Smoking and Drinking Survey of Young People (SDSYP) data).<sup>51</sup> Prevalence ranged from 3% to 32% of children—slightly lower than found in the overview.

### Characteristics of drinkers

In the overview, more boys reported drinking CEDs than girls.<sup>12 29–32</sup> Prevalence by age was inconsistent: for example, within the reviews, one study<sup>48</sup> found that girls started drinking CEDs when they were younger; while one<sup>52</sup> suggested that drinking prevalence peaked at 14 to 15 years; and another<sup>53</sup> suggested that more older boys drank CEDs than younger boys, but more younger girls drank them than older girls. Prevalence by ethnicity was also inconsistent. Children with minority ethnicity drank more than white children,<sup>12 32</sup> but white children drank

more than black or Hispanic children, when drinks were mixed with alcohol.<sup>12</sup> In the UK, drinking was associated with being male, older and lower socioeconomic status.<sup>45</sup>

In the dataset analysis, the SDSYP reported the most detailed information on sociodemographic characteristics. As in most of the overview evidence, prevalence increased with age, so that between a quarter and a third of children aged 15 to 16 years reported consuming one or more CED per week. More boys (29.3%) than girls (18.1%), and more children living in the North of England than in the South (for example, 33.1% in the North-East vs 16.5% in the South-East), consumed at least one can a week. More children who were eligible for free school meals (29.5%), than those who were not eligible (22.6%), drank CEDs weekly. These differences were

**Table 3** Prevalence of CED consumption across datasets by school year (approximately weekly consumption with weighted percentages and unweighted sample sizes - see notes below)

	Year 7 (age 11/12) (% of children)	Year 9 (age 13/14) (% of children)	Year 11 (age 15/16) (% of children)
SDSYP*	12.4 95% CI 10.6 to 14.5 n=1209	24.4 95% CI 21.7 to 27.3 n=1233	31.3 95% CI 28.3 to 34.5 n=1152
HBSC 2013/14†	23.9 95% CI 20.8 to 27.4 n=429	32.3 95% CI 28.5 to 36.4 n=537	29.3 95% CI 26.2 to 32.7 n=459
HBSC 2017/18†	16.4 95% CI 15.4 to 17.4 n=1882	24.2 95% CI 23.1 to 25.4 n=1892	22.9 95% CI 21.6 to 24.3 n=1605
NDNS‡	2.9 95% CI 0.9 to 8.8 n=118	5.4 95% CI 1.9 to 14.6 n=131	6.0 95% CI 2.3 to 14.8 n=138
YPBAS§	16.6 95% CI 14.0 to 19.6 n=756	22.7 95% CI 19.8 to 26.0 n=784	25.4 95% CI 22.0 to 29.1 n=672

\*Measured if children consumed at least one can of CED per week.

†Measured if children drank CED at least 1 day per week; differences in the sampling frame between the two data collection waves (2013/14 and 2017/18) make direct comparison challenging; in the later survey, sample weights were not available for all cases and these findings are only indicative.

‡Data collected through food diaries over a 4 day period.

§Measured if children drank CED at least 1 day per week.

CED, caffeinated energy drink; HBSC, Health Behaviour in School Children; NDNS, National Diet and Nutrition Survey; SDSYP, Smoking and Drinking Survey of Young People; YPBA, Young Persons' Behaviour and Attitudes.

robust to the impact of potential confounders (see the online supplemental file, section 6). Unlike the evidence from the overview, which suggested differences in consumption by ethnicity, the proportion of weekly CED consumers was within 3 percentage points of the average across all ethnic groups.

### Motives and context

Three reviews reported on motives or context for consumption.<sup>12 29 32</sup> The context was parties and socialising with friends or family<sup>12 32 35</sup> or exams.<sup>29</sup> Children's motives included taste (particularly with alcohol), for energy, curiosity, friends drinking them, and parental approval or disapproval. Across the reviews, single studies suggested that more girls than boys drank CEDs to suppress appetite,<sup>54</sup> while more boys than girls drank them for performance in sport.<sup>55</sup> And about half of children knew that the drinks contained caffeine,<sup>56</sup> while those who knew that the content might be harmful drank less.<sup>57</sup>

Motives and context were not measured in the UK datasets.

### RQ2. Associations with drinking CEDs

Fourteen reviews reported associations and are summarised in table 4. Most reviews included cross-sectional evidence (surveys) or individual case studies.

Three reviews<sup>12 40 42</sup> reported prospective trials (four small RCTs in total), which assessed physical performance, cardiovascular response, or the effects of sleep education; one review reported prospective cohort studies.

As most of the evidence was from surveys, measured at a single time-point, cause cannot be distinguished from effect.

### Physical health associations

Associations between drinking CEDs and physical symptoms were reported in all but one<sup>40</sup> of the 14 reviews. CEDs improved sports performance.<sup>58 59</sup> There was consistent evidence of associations with headaches, stomach aches and low appetite,<sup>12 35 42</sup> and with sleep problems.<sup>12 30 35 42</sup> Within the reviews, a trial of boys randomised to receive different doses of CED reported dose-dependent increases in diastolic blood pressure and decreases in heart rate.<sup>60</sup> Across reviews,<sup>34 36–39</sup> nine cases of adverse events were reported; eight children had cardiovascular events, and one had renal failure, following a single drink, moderate drinking, or excessive drinking (in a day or for weeks).

Analysis of the Health Behaviour in School Children (HBSC) 2013/14 data found that children drinking CEDs once a week or more, compared with those drinking less often, were statistically significantly more likely to report physical symptoms occurring more than once a week, such

**Table 4** Characteristics and main findings of the reviews reporting associations with consumption

Review details	Methods and study details	Main findings on associations
Reviews of children or young people		
<b>Reference:</b> Visram (2016) <sup>12</sup> <b>Exposure:</b> CEDs <b>Age:</b> 10 to 21 years	<b>Included:</b> 46 studies (RCTs, surveys and qualitative) <b>Published:</b> 2003 to 2016 <b>Risk of bias tool:</b> CASP and EPHP	<b>Physical:</b> sports performance (2 RCTs), headache, sleep issues, fatigue, stomach aches, hyperactivity, blood pressure (1 RCT) <b>Mental:</b> depression, traumatic experiences <b>Behaviour:</b> sensation seeking, drugs, alcohol, smoking <b>Social:</b> academic performance
<b>Reference:</b> Dawodu (2017) <sup>30</sup> <b>Exposure:</b> CEDs <b>Age:</b> 10 to 18 years	<b>Included:</b> 12 surveys <b>Published:</b> 2013 to 2016 <b>Risk of bias tool:</b> None	<b>Physical:</b> sleep issues, executive function, hyperactivity, inattention <b>Mental:</b> anxiety, depression, anger, impulsivity, self-harm, suicide behaviour <b>Behaviour:</b> risk taking (alcohol, drug taking, smoking) <b>Social:</b> NA
<b>Reference:</b> Bleich and Vercammen (2018) <sup>35</sup> <b>Exposure:</b> Soft drinks (subsection on CEDs) <b>Age:</b> 10 to 18 years	<b>Included:</b> 7 or 8 surveys <b>Published:</b> 2014 to 2016 <b>Risk of bias tool:</b> None	<b>Physical:</b> sleep issues, headaches, stomach aches, appetite <b>Mental:</b> depression, stress, suicide behaviour <b>Behaviour:</b> risk taking (smoking, drugs), ADHD, inattention <b>Social:</b> NA
<b>Reference:</b> Yasuma (2021) <sup>41</sup> <b>Exposure:</b> CEDs <b>Age:</b> 11 to 19 years	<b>Included:</b> 5 prospective cohort studies <b>Published:</b> 2010 to 2019 <b>Risk of bias tool:</b> ROBINS-I	<b>Physical:</b> NA <b>Mental:</b> NA <b>Behaviour:</b> alcohol, smoking, drug use <b>Social:</b> NA
Reviews of children and adults (subsection on children)		
<b>Reference:</b> Alhyas (2016) <sup>29</sup> <b>Exposure:</b> CEDs <b>Age:</b> 12 to 19 years	<b>Included:</b> 5 surveys, 6138 children <b>Published:</b> 2011 to 2014 <b>Risk of bias tool:</b> None	<b>Physical:</b> increased energy level, voice tone changes, menstrual changes <b>Mental:</b> mood changes <b>Behaviour:</b> NA <b>Social:</b> NA
<b>Reference:</b> Roemer (2017) <sup>31</sup> <b>Exposure:</b> Alcohol mixed with CEDs <b>Age:</b> 11 to 20 years	<b>Included:</b> 3 surveys <b>Published:</b> 2014 to 2015 <b>Risk of bias tool:</b> No tool, some assessment	<b>Physical:</b> traumatic brain injuries, alcohol-related injuries, car crashes <b>Mental:</b> NA <b>Behaviour:</b> unsafe driving, binge drinking <b>Social:</b> NA
<b>Reference:</b> Verster (2018) <sup>32</sup> <b>Exposure:</b> Alcohol mixed with CEDs <b>Age:</b> 14 to 19 years	<b>Included:</b> 6 surveys <b>Published:</b> 2013 to 2016 <b>Risk of bias tool:</b> None	<b>Physical:</b> traumatic brain injury <b>Mental:</b> no differences in mental health <b>Behaviour:</b> risky behaviour (drugs, alcohol, smoking, violence, sexual behaviour) <b>Social:</b> school absence, academic achievement (some studies found no association)
<b>Reference:</b> Richards and Smith (2016) <sup>40</sup> <b>Exposure:</b> CEDs <b>Age:</b> 9 to 24 years	<b>Included:</b> 7 surveys, 1 RCT <b>Published:</b> 2010 to 2015 <b>Risk of bias tool:</b> None	<b>Physical:</b> NA <b>Mental:</b> post-traumatic stress disorder, stress, anxiety, depression (some studies found no effect), self-harm, suicidal thoughts, and well-being <b>Behaviour:</b> Improvements in behaviour and mental health with better sleep (and fewer CEDs – in an RCT) <b>Social:</b> NA

Continued

Table 4 Continued

Review details	Methods and study details	Main findings on associations
<b>Reference:</b> Nadeem (2021) <sup>42</sup> <b>Exposure:</b> CEDs <b>Age:</b> 11 to 19 years	<b>Included:</b> 9 surveys, 1 RCT <b>Published:</b> 2014 to 2018 <b>Risk of bias tool:</b> MINORS	<b>Physical:</b> cardiovascular, gastrointestinal, immune, muscular, neurological, physiological, renal (ranging from 8–35% of children) <b>Mental:</b> stress, depression, and suicidal thoughts/attempt (20–35% of children) <b>Behaviour:</b> NA <b>Social:</b> NA
Reviews of case reports (excluding adults)		
<b>Reference:</b> Ali (2015) <sup>34</sup> <b>Exposure:</b> CEDs <b>Age:</b> 13 to 17 years	<b>Included:</b> 4 cases (all male) <b>Published:</b> 2011 to 2012 <b>Risk of bias tool:</b> None	<b>Physical:</b> palpitations, angina <b>Mental:</b> NA <b>Behaviour:</b> NA <b>Social:</b> NA
<b>Reference:</b> Buck (2013) <sup>36</sup> <b>Exposure:</b> CEDs <b>Age:</b> 13 to 16 years	<b>Included:</b> 3 cases <b>Published:</b> 2008 to 2012 <b>Risk of bias tool:</b> None	<b>Physical:</b> arrhythmia, palpitations, tachycardia, systolic murmur, chest pain <b>Mental:</b> NA <b>Behaviour:</b> NA <b>Social:</b> NA
<b>Reference:</b> Bull (2015) <sup>37</sup> <b>Exposure:</b> CEDs <b>Age:</b> 10 to 17 years	<b>Included:</b> 2 cases <b>Published:</b> 2011 <b>Risk of bias tool:</b> None	<b>Physical:</b> renal failure, jitteriness <b>Mental:</b> NA <b>Behaviour:</b> NA <b>Social:</b> NA
<b>Reference:</b> Goldfarb (2014) <sup>38</sup> <b>Exposure:</b> CEDs <b>Age:</b> 13 to 17 years	<b>Included:</b> 5 cases <b>Published:</b> 2011 to 2012 <b>Risk of bias tool:</b> None	<b>Physical:</b> cardiovascular events (palpitations, chest pain, dizziness, tremors) <b>Mental:</b> NA <b>Behaviour:</b> NA <b>Social:</b> NA
<b>Reference:</b> Lippi (2016) <sup>39</sup> <b>Exposure:</b> CEDs <b>Age:</b> 13 to 17 years	<b>Included:</b> 2 cases <b>Published:</b> 2012 to 2013 <b>Risk of bias tool:</b> None	<b>Physical:</b> ST elevation myocardial infarction (angina, coronary artery dissection) <b>Mental:</b> NA <b>Behaviour:</b> NA <b>Social:</b> NA

ADHD, attention deficit hyperactivity disorder; CASP, Critical Appraisal Skills Programme; CEDs, caffeinated energy drinks; EPHPP, Effective Public Healthcare Panacea Project; MINORS, methodological index for non-randomized studies; NA, not applicable; NR, not reported; RCT, randomised controlled trial; ROBINS-I, Risk Of Bias In Non-randomised Studies - of Interventions.

as headaches (22.2% vs 16.8%), sleep problems (13.6% vs 8.5%) and stomach problems (31.2% vs 23.1%).

### Mental health associations

Associations between drinking CEDs and mental health were inconsistent.<sup>12 29 30 32 35 40 42</sup> One review reported that improvements in mental health and hyperactivity were found in children who were randomised to receive an intervention to lower their intake of CEDs.<sup>61</sup> Associations were found with stress, anxiety or depression,<sup>12 30 35 40 42</sup> but two reviews<sup>12 40</sup> also found studies that did not find an association. Some reviews included evidence of associations with self-harm or suicidal behaviour,<sup>30 35 40 42</sup> and with irritation and anger.<sup>12 30 35 40 42</sup>

Secondary analyses of the HBSC 2013/14 data found that children who consumed CEDs at least once a week were statistically significantly more likely, than those who

did not, to report low mood (20.3% vs 14.9%) and irritability (30.8% vs 18.0%) on a weekly basis.

### Behavioural associations

Some evidence of associations between drinking CEDs and behaviour was reported.<sup>12 30–32 35 42</sup> Drinking CEDs was associated with alcohol, smoking and substance misuse at a single time point,<sup>12 30 35</sup> and at follow-up.<sup>41</sup> CED consumption at baseline predicted alcohol consumption at follow-up.<sup>12</sup> Consumption was associated with increased hyperactivity and inattention, and with sensation seeking.<sup>12 30 35</sup> Injuries were associated with drinking CEDs with alcohol<sup>12 31</sup> and without alcohol.<sup>12 30</sup>

Analysis of the SDSYP data found that higher proportions of children who consumed one or more cans per week had tried alcohol (59.1%) and smoking (39.7%),



compared with non-CED consumers (alcohol 28.9%, smoking 10.4%).

### Social or educational associations

Consistent associations between drinking CEDs and social or educational outcomes were reported.<sup>12 32</sup> Within reviews, one UK study<sup>45</sup> found an association between drinking CEDs once a week or more and poor school attendance. CEDs mixed with alcohol were associated with lower grades and more absence from school.<sup>32</sup>

Analysis of the SDSYP data found that almost half of children who had been truant or excluded reported drinking a can of CED on a weekly basis (49.5%), compared with less than a fifth of those who had not been truant or excluded (18.5%).

### Well-being profiles

Using the HBSC 2013/14 dataset, we identified 11 indicators of well-being: weekly experience of irritability, sleep difficulties, nervousness, dizziness, headaches, stomach aches, and low mood; as well as low life satisfaction, feeling pressured by schoolwork some or a lot of the time, dislike of school, and low self-rated academic achievement. From these, using LCA, we identified five profiles: low psychological well-being (18.2% of children), high overall well-being (48.6%), low educational well-being (6.7% of children), low physical well-being (13.0%), and low overall well-being (13.5%). See the online supplemental file (section 6) for details.

After controlling for age, gender, rurality, smoking status, alcohol status and Family Affluence Scale (a measure of socioeconomic status; for more information see Hartley *et al*<sup>62</sup>), the relative risk of having a low well-being profile, compared with a high well-being profile, was substantially higher for children who consumed CEDs at least 5 days a week (frequent), compared with those who rarely or never did. Relative to a high well-being profile, frequent consumers had a higher risk of low psychological well-being (RR 2.11, 95% CI 1.56 to 2.85) and low physical well-being (RR 2.52, 95% CI 1.76 to 3.61), and were over four times more likely to have low educational well-being (RR 4.81, 95% CI 3.59 to 6.44) and low overall well-being (RR 4.15, 95% CI 2.85 to 6.00). These data suggest that CED consumption is a marker of low well-being, but the analyses also showed that consumption was one of a cluster of factors (eg, smoking and drinking alcohol) in children with low well-being.

## DISCUSSION

### Summary of the evidence

Prevalence varied according to the measures used and the ages of children. In the overview, CED consumption prevalence was up to 67% of children in the past year and, in the dataset analyses, up to 32% of children were consuming a CED at least 1 day a week, meaning that up to a third of UK children are regularly consuming caffeine. Evidence from the overview and the dataset

analyses consistently suggests that boys drink more than girls, and that drinking tends to increase with age. Some evidence from the overview suggested higher prevalence in children from ethnic minority backgrounds, but no such association was detected in the UK data analysis. This could be due to factors such as area of residence or social class affecting well-being in children from ethnic minorities, where well-being is driving the differences in prevalence of CED consumption, rather than minority background. Reviews included in the overview found that most drinking of CEDs occurred at parties, around exams, with friends, or with family, and motives included taste, energy, curiosity, appetite suppression, and sports performance, which was reported to be improved. There was some evidence that knowledge of content was low, and that children who knew that the content might be harmful drank less, suggesting that education could reduce drinking.

Evidence from the overview suggests worse sleep, and raised blood pressure, with CED consumption, compared with reduced or no consumption. Both the overview and the dataset analysis found that children who consumed CEDs reported headaches, stomach aches and sleep issues more frequently than those who did not; although most studies were cross-sectional, some in the overview were longitudinal, showing changes over time.<sup>18</sup> The overview identified consistent evidence of associations with self-harm, suicide behaviour, alcohol use\*, smoking\*, substance misuse\*, hyperactivity, irritation\*, anger, and school performance, attendance, and exclusion (\*also found in the UK dataset analysis). This was consistent with findings reported in non-systematic reviews.<sup>10 63 64</sup>

The UK dataset analysis suggested that children who consumed CEDs 5 or more days a week had lower psychological, physical, educational and overall well-being than non-drinkers. It remains unclear whether drinking CEDs contributes to low well-being, or low well-being leads to CED consumption, or both. Alternatively, there may be a common cause, such as social inequality.

### Strengths and limitations

The overview was limited by the amount of information reported in the included systematic reviews, and by their method limitations; all had a high risk of bias. They mainly included cross-sectional surveys or case reports, which means that cause or effect cannot be determined where an association is found. However, some prospective studies, including four small RCTs, were included in the reviews and where there were common measures, the evidence from these RCTs and from most of the cross-sectional studies within the reviews was consistent. This suggests that the associations found could be reliable. A strength of our work is that the UK evidence in the overview (two studies within the reviews) was supplemented by the analysis of UK data, which was mostly consistent with the non-UK evidence. These data support the idea that there is a link between drinking CEDs and poorer health and behaviour in children, although the cause

is unclear. Overlap between reviews in the overview was slight (unsurprisingly, given the different foci of the reviews). There was no overlap between the reviews and the dataset analysis, meaning that the latter added new information. The wide range of tools used to measure prevalence made it difficult to summarise the overview evidence, and meta-analysis of the individual participant UK data was not possible, meaning that the conclusions are based on weaker evidence from single sources.

### Recommendations for research

Standardisation is needed in the measurement of the prevalence of drinking—defining the dosage (in drinks and/or caffeine), timing (daily, weekly, etc) and population (age, ethnicity, etc). There was little evidence on children under 12 years old, and both the overview and dataset analysis found little evidence from the UK. Longitudinal data, from the UK datasets, should be collected to understand better the impact of consumption. RCTs may not be ethical, even where benefits are predicted, such as where children who consume CEDs are randomised to interventions to reduce or stop their drinking to see if this improves their well-being.

### Conclusion

Based on a comprehensive overview of available systematic reviews, we conclude that up to half of children, worldwide, drink CEDs weekly or monthly, and based on the dataset analysis, up to a third of UK children do so. There is weak but consistent evidence, from reviews and UK datasets, that poorer health and well-being is found in children who drink CEDs. In the absence of RCTs, which are unlikely to be ethical, longitudinal studies could provide stronger evidence.

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**Data availability statement** Data are available upon reasonable request. All the data in the overview are publicly available, but not necessarily without charge. Those for the dataset analysis are available from the UK Data Service.

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## Supplementary file

### Section 1: Databases searched and MEDLINE search strategy

The following databases were searched: Bielefeld Academic Search Engine (BASE); BIOSIS (Web of Science); Google Scholar; MEDLINE (OVID); PsycInfo (OVID); Scopus; Web of Science Citation Indexes: Emerging Sources Citation Index, Science Citation Index, Social Sciences Citation Index.

#### MEDLINE search strategy

Databases: Ovid MEDLINE(R) Epub Ahead of Print, In-Process & Other Non-Indexed Citations, Ovid MEDLINE(R) Daily and Ovid MEDLINE(R) <1946 to Present>

Date searched: 15 May 2018

No. of results: 99

1 ((energy adj3 drink?) or (energy adj3 beverage?) or (soft adj3 drink?) or (soft adj3 beverage?) or (carbonated adj3 drink?) or (carbonated adj3 beverage?) or (sport? adj3 drink?) or (sport? adj3 beverage?) or (sugar? adj3 drink?) or (sugar? adj3 beverage?) or (soda? adj3 drink?) or (soda? adj3 beverage?) or (flavor\* adj3 drink?) or (flavor\* adj3 beverage?) or (flavour\* adj3 drink?) or (flavour\* adj3 beverage?) or (sweet\* adj3 drink?) or (sweet\* adj3 beverage?)).ti,ab,kw. (9509)

2 (caffeine\* or guarana).ti,ab,kw. or Caffeine/ (32008)

3 1 and 2 (852)

4 exp Energy drinks/ (551)

5 3 or 4 (1150)

6 (((("synthesis" or "systematic") and ("evidence" or "research" or "review")) or ("review" and (integrat\* or critical\* or "mapping" or "comprehensive" or "evidence" or "research" or "literature")))).ti. or ((systematic adj2 review\*) or ("meta-analysis" or "Review articles" or "systematic review\*" or "Overview of reviews" or "Review of Reviews") or ("data synthesis" or "evidence synthesis" or "metasynthesis" or "meta-synthesis" or "narrative synthesis" or "qualitative synthesis" or "quantitative synthesis" or "realist synthesis" or "research synthesis" or "synthesis of evidence" or "thematic synthesis" or "systematic map\*" or "metaanaly\*" or "meta-analy\*" or "systematic overview\*" or "systematic review\*" or "systematically review\*" or "bibliographic search" or "database search" or "electronic search" or "handsearch\*" or "hand search\*" or "keyword search" or "literature search" or "search term\*" or "literature review" or "overview of reviews" or "review literature" or "reviewed the literature" or "reviews studies" or "scoping stud\*" or "overview study" or "meta-ethnograph\*" or "meta-epidemiological" or "data extraction" or "meta-regression" or "narrative review" or "art review" or "scoping review" or "iterative review" or "meta-summary"))).ti,ab,kw. (421553)

7 limit 5 to (meta analysis or "review" or systematic reviews) (148)

8 5 and 6 (49)

9 7 or 8 (158)

10 limit 9 to yr="2013 -Current" (99)

The searches were re-run on 2<sup>nd</sup> July 2021.



## Section 2: Articles excluded at full-text assessment

### Original search on 15<sup>th</sup> May 2018 – excluded on full text

#### Excluded as Not in English

1. Manrique CI, Arroyave-Hoyos CL, Galvis-Pareja D (2018) CEDs: Neurological and cardiovascular effects. *latreia* 31: 65-75.
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#### Excluded on Design – not a systematic review

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**Excluded on Exposure – not about CEDs (or no section on ED)**

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**Excluded on Population – not about Children (or no separate data for children)**

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**Excluded on Data – no extractable relevant data**

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**Search update on 2<sup>nd</sup> July 2021 – excluded on full text****Duplicate**

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**Excluded on Design – not a systematic review**

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**Excluded on Exposure – not about CEDs (or no section on ED)**

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**Excluded on Population – not about Children (or no separate data for children)**

1. Alwis Upeksha S, Haddad R, Monaghan Thomas F, Abrams P, Dmochowski R, Bower W, et al. Impact of food and drinks on urine production: a systematic review. *International Journal of Clinical Practice*. 2020;74(9):e13539.
2. Arias-Oviedo GM, Castillo-Hernandez I, Jimenez-Diaz J. Meta-analysis of the acute effect of energy drinks on anaerobic performance: a meta-analysis. *Pensar En Movimiento-Revista De Ciencias Del Ejercicio Y La Salud*. 2019;17(2):23.
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**Excluded on Data – no extractable relevant data**

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### Section 3: Characteristics and summaries of the two additional included systematic reviews

First Author (Year) and Review aims	Methods	Population	Exposure and Outcomes
<b>Nadeem (2021)</b> <i>- Canada</i>  <b>Aims of the review</b> <i>- To evaluate and report potential adverse health effects after consumption of energy drinks</i>  <b>Focus</b> Health effects  <b>Funding</b> <i>- Not reported</i>	<b>Sources searched</b> <i>- PubMed and EMBASE</i>  <b>Search range of dates</b> <i>- Inception to November 2019</i>  <b>Number of primary studies</b> <i>- 10 out of 32 on children</i>  <b>Country of relevant studies</b> North America - <i>n</i> =2 Europe (non-UK) - <i>n</i> =1 Asia - <i>n</i> =1 Australia - <i>n</i> =1  <b>Design of relevant studies</b> Surveys - <i>Nine cross-sectional</i> Intervention - <i>One RCT</i>	<b>Target population</b> General - adults and children  <b>Participant age</b> Whole review <i>: 11 to 63 years (mean 15.2)</i> Relevant studies <i>- 11 to 19 years</i>  <b>Participant gender</b> Whole review <i>- 52.1% (49,219/94,438) male</i> Relevant studies <i>- not reported</i>  <b>Participant SES</b> Whole review <i>- not reported</i> Relevant studies <i>- not reported</i>	<b>Number/frequency of drinks</b> <i>- 8/10 reported frequency ranging from &lt;1 per year to &gt;1 per day</i>  <b>Caffeine content</b> <i>- not reported</i>  <b>Social context of intake</b> <i>- three studies reported - energy, awake, education settings</i>  <b>Named drink/s</b> <i>- Fure (one study)</i>  <b>Physical effects</b> <i>- Cardiovascular, gastrointestinal, immune, muscular, neurological, physiological, renal</i>  <b>Mental effects</b> <i>- Stress, depressive mood, suicide ideation/plan/attempt, agitation, irritable</i>
<b>Yasuma (2021)</b> <i>- Japan</i>  <b>Aims of the review</b> <i>- To examine the association between ED consumption and SU in adolescence, focusing on prospective cohort studies.</i>  <b>Focus</b> Health effects  <b>Funding</b> <i>- No funding</i>	<b>Sources searched</b> <i>- PubMed, Embase, PsycINFO/ARTICLES and the Japan Medical Abstracts Society database</i>  <b>Search range of dates</b> <i>- Up to 14th August 2019</i>  <b>Number of primary studies</b> <i>- Five</i>  <b>Country of relevant studies</b> North America – <i>n</i> =4 Europe (non-UK) – <i>n</i> =1  <b>Design of relevant</b>	<b>Target population</b> Children in general  <b>Participant age</b> Whole review <i>- 11 to 19 years</i> Relevant studies <i>- 11 to 19 years</i>  <b>Participant gender</b> Whole review <i>- not reported</i> Relevant studies <i>- not reported</i>  <b>Participant SES</b> Whole review <i>- not reported</i> Relevant studies <i>- not reported</i>	<b>Number/frequency of drinks</b> <i>- Amount or frequency over one week to four months.</i>  <b>Caffeine content</b> <i>- not reported</i>  <b>Social context of intake</b> <i>- Not reported</i>  <b>Named drink/s</b> <i>- Two studies mentioned Red Bull, Monster, Rock Star, Full Throttle or other drinks</i>  <b>Behavioural Effects</b> <i>- Alcohol, tobacco and</i>



	<b>studies</b> <i>- All were prospective cohort, with exposure to ED determined by self-report questionnaire</i>		<i>drug use (illicit and prescription drugs and analgesics)</i>
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**Yasuma N, Imamura K, Watanabe K, Nishi D, Kawakami N, Takano A. (2021). Association between energy drink consumption and substance use in adolescence: a systematic review of prospective cohort studies. *Drug and Alcohol Dependence* 219:108470.**

This systematic review (Yasuma 2021) aimed to examine the association between energy drink consumption and substance use in adolescence, focusing on prospective cohort studies. Five studies were included (published between 2010 and 2019), involving 2,863 children aged 11 to 19 years, residing in the USA (four studies) or Switzerland (one study).

All of four studies found an association between energy drink and alcohol use at follow-up. One of two studies found an association with smoking and illicit drugs (two years later), but the other study did not (one year later).

This review was rated as 'low' using the AMSTAR 2 critical appraisal tool, with no list of excluded studies and no description of the included studies' funding sources. The five included studies were rated as being at severe risk of bias. Four of them were conducted in the USA, so the results may not be applicable to other countries.

**Nadeem IM, Shanmugaraj A, Sakha S, Horner NS, Ayeni OR, Khan M. (2021). Energy Drinks and Their Adverse Health Effects: A Systematic Review and Meta-analysis. *Sports Health* 13(3):265-277.**

This systematic review (Nadeem 2021) aimed to evaluate and report potential adverse health effects after consumption of energy drinks. Of the 32 studies included, one RCT and nine cross-sectional studies (published between 2014 and 2018) involved 89,836 adolescents and children aged 11 to 19 years. These studies on children were conducted in a range of non-UK countries (Australia, Iceland, Korea, Poland, Portugal, Slovakia, Spain and USA).

Across the 10 studies, the reported physical symptoms were palpitations (17.5%; 174/995), chest pain (19.6%; 154/786), dyspnoea (17.1%; 134/784), tachycardia (12.5%; 127/1016), abdominal pain (14.5%; 1691/11,637), low appetite (17.3%; 256/1483), gastrointestinal upset (9.3%; 83/893) muscle soreness or backache (14.4%; 1266/8803), headaches (20.9%; 2501/11,972), dizziness (10.0%; 885/8875), tremors (8.1%; 130/1606), insomnia/sleeping-related symptoms (35.4%; 28,371/80,173), weakness (28.9%; 172/596), dehydration (20.8%; 123/592), and increased urination (16.4%; 97/592). No children reported allergic reactions.

The reported mental health effects were stress (35.4%; 24,054/68,043), depressive mood (23.1%; 17,757/76,859), and suicidal ideation/plan/attempt (19.8%; 15,278/77,004).

This review was rated as 'critically low' using the AMSTAR 2 critical appraisal tool. There was no report of a protocol, and very little description of the search. The quality of the included studies was assessed, using MINORS, and was described as fair for all studies, not just studies of children. This review focussed on energy drinks, with a short section on children.

## Section 4: Quality assessment of the included reviews for efficacy and safety, genotyping, and self-monitoring

First author (year)	1. PICO components	2. Protocol	3. Study design explanation	4. Comprehensive search strategy	5. Duplicate study selection	6. Duplicate data extraction	7. Details of excluded studies	8. Description of included studies	9a. Risk of Bias assessment (RCTs)	9b. Risk of Bias assessment (NRSIs)	10. Funding source	11a. RCTs Meta-analysis	11b. NRSIs Meta-analysis	12. Meta-analysis: RoB in individual studies	13. RoB: discussion of results	14. Heterogeneity	15. Publication bias	16. Reporting of conflict of interest	Relevance	Overall rating
Alhyas (2016)	Y	N	N	P	N	N	N	P	NA	N	N	NA	Y	N	N	N	N	Y	P	CL
Ali (2015)	N	N	N	P	Y	N	N	P	NA	N	N	NA	NA	NA	N	N	NA	Y	P	CL
Bleich (2018)	Y	N	N	P	N	N	N	Y	NA	N	N	NA	NA	NA	N	N	NA	Y	P	CL
Buck (2013)	Y	N	N	P	N	Y	N	N	NA	N	N	NA	NA	NA	N	N	NA	Y	P	CL
Bull (2015)	Y	Y	N	P	Y	Y	P	P	NA	P	N	NA	NA	NA	N	Y	NA	N	P	Low
Dawodu (2017)	Y	N	N	P	Y	N	N	P	NA	N	N	NA	NA	NA	N	N	NA	Y	Y	CL
Goldfarb (2014)	N	N	Y	P	Y	N	N	P	NA	N	N	NA	NA	NA	N	Y	NA	Y	P	CL
Lippi (2016)	N	N	Y	P	Y	N	N	P	NA	N	N	NA	NA	NA	Y	Y	NA	Y	P	CL
Nadeem (2021)	Y	N	N	N	Y	Y	N	P	N	P	N	NA	NA	NA	N	Y	NA	Y	P	CL
Richards (2016)	N	N	N	P	N	N	N	Y	N	N	N	NA	NA	NA	Y	N	NA	Y	P	CL
Roemer (2017)	N	P	N	P	N	Y	N	Y	NA	P	N	NA	NA	NA	Y	Y	NA	Y	P	CL
Verster (2017)	N	N	Y	P	N	N	N	P	N	N	N	N	N	N	N	N	N	Y	P	CL
Verster (2018)	Y	N	Y	P	N	N	N	P	NA	N	N	NA	NA	NA	Y	Y	NA	Y	P	CL
Visram (2016)	Y	P	Y	P	Y	N	N	Y	Y	Y	N	NA	NA	NA	Y	Y	NA	Y	Y	Low
Yasuma (2021)	Y	Y	Y	P	Y	Y	N	Y	NA	Y	N	NA	NA	NA	Y	Y	NA	Y	Y	Low

P = partial yes, NA = not applicable, CL = critically low, Y = yes, N = no, RoB = risk of bias, MA = meta-analysis, PICO = participants, intervention, comparator & outcome

**High** - Zero or one non-critical\* weakness: The systematic review provides an accurate and comprehensive summary of the results of the available studies that address the question of interest. **Moderate** - More than one non-critical weakness: The systematic review has more than one weakness, but no critical flaws. It may provide an accurate summary of the results of the available studies that were included in the review. **Low** - One critical flaw with or without non-critical weaknesses: The review has a critical flaw and may not provide an accurate and comprehensive summary of the available studies that address the question of interest. **Critically low** - More than one critical flaw with or without non-critical weaknesses: The review has more than one critical flaw and should not be relied on to provide an accurate and comprehensive summary of the available studies. \*Critical domains: 2, 4, 7, 9, 11, 13 and 15.<sup>16</sup>

### Section 5: Overlap in studies included in reviews for each section

The calculation for the corrected covered area is  $(n-r)/(rc-r) \times 100$  (for percentage), where  $r$  is the number of rows (primary studies),  $c$  is the number of columns (reviews) and  $n$  is the total number of included studies (with double counting). Values of 0-5 are considered slight, 6-10 moderate, 11-15 high and over 15 very high.

$c=15$  reviews,  $r=85$  studies,  $n=123$ ,  $CCA=3.2\%$  - slight overlap

	Review	Nadeem 2021	Yasuma 2021	Bleich 2018	Verster Koenig 2018	Verster 2018	Dawodu 2017	Roemer 2017	Alhyas 2016	Lippi 2016	Richards 2016	Visram 2016	Ali 2015	Bull 2015	Goldfarb 2014	Buck 2013	Overlap
	Included Studies																
1	*Abian-Vicen (2014)	√										√					2
2	Al-Hazaa (2011)								√								
3	Al-Hazaa (2014)											√					
4	Almalak (2014)								√								
5	Aluqmany (2013)								√								
6	Arria (2010)		√														
7	Arria (2014)											√					
8	*Azagba (2013)					√						√					2
9	*Azagba (2014)			√			√				√	√					4
10	*Azagba & Sharaf (2014)					√						√					2
11	Barrense-Dias (2016)		√														
12	*Bashir (2016)	√		√													2
13	Beckford (2015)				√												
14	Branum (2014)				√												
15	Bryant Ludden (2010)											√					
16	Bunting (2013) <sup>1</sup>											√					
17	*Choi (2016)		√									√					2
18	Cotter (2013)											√					
19	Costa (2014)											√					
20	Costa (2016)	√															
21	*Di Rocco (2011)												√ <sup>5</sup>		√	√	3
22	*Dufendach (2012)/Gray (2012) <sup>2</sup>														√	√	2
23	EFSA (2015)				√												
24	*Emond (2014)						√					√					2
25	*Evren (2015)						√				√	√					3
26	Faris (2015)											√					
27	Flotta (2014)					√											

	Review	Nadeem 2021	Yasuma 2021	Bleich 2018	Verster Koenig 2018	Verster 2018	Dawodu 2017	Roemer 2017	Alhyas 2016	Lippi 2016	Richards 2016	Visram 2016	Ali 2015	Bull 2015	Goldfarb 2014	Buck 2013	Overlap
	Included Studies																
28	Galaxy poll (ABC) (2013)				√												
29	*Gallimberti (2013)						√					√					2
30	Gallimberti (2015)											√					
31	Gallo-Salazar (2015)											√					
32	Gambon (2011)											√					
33	Gunja (2012)											√					
34	*Hamilton (2013)						√					√					2
35	Hernandez (2009)											√					
36	Holubcikova (2017)	√															
37	Huhtinen (2013)											√					
38	*Ilie (2015)							√				√					2
39	*Izquierdo 2012												√		√		2
40	Jones (2011)											√					
41	Kilani (2013)								√								
42	Kim (2018)	√															
43	*Koivusilta (2016)			√								√					2
44	Kponee (2014)							√									
45	*Kristjansson (2014)	√		√								√					3
46	Kumar (2014)											√					
47	Lachenmeier (2013)				√												
48	*Larson (2014)						√					√					2
49	Locatelli (2012)											√					
50	Lubman (2014)											√					
51	*Magnezi (2015)					√						√					2
52	Marmorstein (2016)			√													
53	Marmorstein (2019)		√														
54	Martins (2018)	√															
55	*Martz (2015)					√		√				√					3
56	Mitchell (2014)				√												
57	*Miyake (2015)		√				√					√					3
58	*Musaiger (2014)								√			√					2
59	NZCNS (2002)				√												
60	Nordt (2017)	√															
61	*Nowak (2015)						√					√					2
62	Nowak (2016)	√															
63	O'Dea (2003)											√					
64	Park (2012)											√					



	Review	Nadeem 2021	Yasuma 2021	Bleich 2018	Verster Koenig 2018	Verster 2018	Dawodu 2017	Roemer 2017	Alhyas 2016	Lippi 2016	Richards 2016	Visram 2016	Ali 2015	Bull 2015	Goldfarb 2014	Buck 2013	Overlap
	Included Studies																
65	*Park (2016)	√		√													2
66	Peters (2010)										√						
67	Polat (2013)									√							
68	Reid (2015)											√					
69	*Richards & Smith (2015) <sup>3</sup>			√							√						2
70	Richards (2015)										√						
71	Richards (2016)											√					
72	Schoffl (2011)													√			
73	*Schwartz (2015)						√					√					2
74	*Seifert (2011) <sup>4</sup>											√		√			2
75	Seifert (2013)											√					
76	Temple (2010)											√					
77	Terlizzi (2008)															√	
78	*Terry-McElrath (2014)						√					√					2
79	Tucker (2016)					√											
80	Usman (2012)												√				
81	*Van Batenburg-Eddes (2014)						√					√					2
82	*Vilija (2014)										√	√					2
83	*Wilson (2012)									√			√		√		3
84	Wing (2015)										√						
85	Zucconi (2013)				√												
	Totals	10	5	7	8	6	11	3	5	2	7	46	4	2	4	3	

\*cited in more than one included review.

<sup>1</sup> The study by Bunting et al (2013) collected data from focus groups participants aged (16–21). The proportion of the sample that was under 18 years old is not reported.

<sup>2</sup> Buck et al. (2013) detailed a case cited by Gray et al (2012). However, in the paper by Gray et al., the same case is attributed to Dufendach et al. (2012).

<sup>3</sup> The three papers by Richards et al. report outcomes from one research study

<sup>4</sup> Seifert et al. (2011) is a review not a primary study

<sup>5</sup> The study by Di Rocco et al. (2011) was not cited in the review by Ali et al (2015). However, one of the age-relevant cases included in the Ali et al. (2015) review was consistent with the details reported by Di Rocco and so was attributed to that paper.

Section 6: Dataset analysis tables

Table 1. Smoking & Drinking Survey: Frequency of Caffeinated Energy drink use by Gender

		Boy	Girl	Total
Never	Weighted %	23.9	36.9	30.4
	Unweighted N	736.0	1068.0	1804.0
Not in past week	Weighted %	39.0	37.9	38.5
	Unweighted N	1145.0	1107.0	2252.0
Less than a can	Weighted %	7.8	7.1	7.4
	Unweighted N	235.0	213.0	448.0
One can or more	Weighted %	29.3	18.1	23.7
	Unweighted N	917.0	566.0	1483.0
Total	%	100.0	100.0	100.0
	Unweighted N	3033.0	2954.0	5987.0
	Weighted N	3019.6	2975.0	5994.6
Observations		5987		
P		<0.001		

**Table 2. Smoking & Drinking Survey: Frequency of Caffeinated Energy Drink use by Region**

		North East	North West	Yorks. and Humber	East Midlands	West Midlands	East of England	London	South East	South West	Total
Never	Weighted %	23.8	27.3	28.4	28.9	26.6	30.0	33.1	34.3	34.7	30.4
	Unweighted N	175.0	166.0	160.0	184.0	214.0	213.0	230.0	256.0	206.0	1804.0
Not in past week	Weighted %	34.3	37.7	33.5	37.2	39.5	36.8	39.8	41.8	40.6	38.5
	Unweighted N	248.0	222.0	185.0	225.0	307.0	254.0	267.0	301.0	243.0	2252.0
Less than a can	Weighted %	8.9	7.5	8.4	8.0	6.2	8.1	7.2	7.4	6.2	7.4
	Unweighted N	65.0	45.0	46.0	48.0	49.0	57.0	48.0	53.0	37.0	448.0
One can or more	Weighted %	33.1	27.4	29.6	26.0	27.6	25.1	19.9	16.5	18.6	23.7
	Unweighted N	240.0	162.0	161.0	157.0	219.0	174.0	133.0	122.0	115.0	1483.0
Total	%	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	Unweighted N	728.0	595.0	552.0	614.0	789.0	698.0	678.0	732.0	601.0	5987.0
	Weighted N	275.6	793.8	602.6	515.1	650.6	690.6	879.3	1001.4	585.6	5994.6
Observations		5987									
P		<0.001									

**Table 3. Smoking & Drinking Survey: Frequency of Caffeinated Energy Drink use by Free School Meals Eligibility**

		Not eligible for free school meals	Eligible for free school meals	Total
Never	Weighted %	30.9	26.3	30.2
	Unweighted N	1544.0	217.0	1761.0
Not in past week	Weighted %	39.4	34.6	38.7
	Unweighted N	1927.0	299.0	2226.0
Less than a can	Weighted %	7.1	9.6	7.4
	Unweighted N	353.0	87.0	440.0
One can or more	Weighted %	22.6	29.5	23.6
	Unweighted N	1169.0	282.0	1451.0
	%	100.0	100.0	100.0
Total	Unweighted N	4993.0	885.0	5878.0
	Weighted N	5012.2	874.1	5886.3
Observations		5878		
P		<0.001		

**Table 4. Smoking & Drinking Survey: Logistic regression annotated output – odds of consuming at least one can of CED a week**

	Covariate	Odds Ratio	Lower 95% CI	Upper 95% CI
Year	Year 7 ( <i>baseline</i> )	1.000	1.000	1.000
	Year 8	1.717	1.344	2.192
	Year 9	1.965	1.571	2.459
	Year 10	2.070	1.644	2.605
	Year 11	1.964	1.563	2.469
Gender	Boys ( <i>baseline</i> )	1.000	1.000	1.000
	Girls	0.528	0.446	0.624
Region	North East ( <i>baseline</i> )	1.000	1.000	1.000
	North West	0.763	0.533	1.093
	Yorkshire & Humber	0.835	0.610	1.143
	East Midlands	0.736	0.508	1.065
	West Midlands	0.751	0.550	1.025
	East of England	0.641	0.457	0.900
	London	0.474	0.328	0.686
	South East	0.371	0.257	0.535
	South West	0.443	0.318	0.617
FSM	Not eligible for FSM ( <i>baseline</i> )	1.000	1.000	1.000
	FSM (Free School Meals)	1.323	1.088	1.610
Truant	Not truant/excluded ( <i>baseline</i> )	1.000	1.000	1.000
	Truanted/excluded	3.032	2.566	3.583
Smoker	Doesn't smoke ( <i>baseline</i> )	1.000	1.000	1.000
	Current smoker	2.641	1.918	3.638
Alcohol	No alcohol in past week ( <i>baseline</i> )	1.000	1.000	1.000
	Alcohol in past week	2.081	1.597	2.712
Unweighted N=5,834				



**Table 5. Smoking & Drinking Survey: Frequency of Caffeinated Energy Drink use by Ethnicity**

		White	Mixed	Asian	Black	Other	Total
Never	Weighted %	30.8	26.0	30.4	24.2	32.3	30.3
	Unweighted N	1436.0	64.0	139.0	57.0	18.0	1714.0
Not in past week	Weighted %	37.6	44.9	41.4	43.6	41.4	38.6
	Unweighted N	1764.0	106.0	188.0	89.0	23.0	2170.0
Less than a can	Weighted %	7.5	8.0	6.9	6.8	2.9	7.4
	Unweighted N	359.0	19.0	33.0	13.0	2.0	426.0
One can or more	Weighted %	24.1	21.2	21.2	25.4	23.4	23.8
	Unweighted N	1197.0	58.0	96.0	55.0	14.0	1420.0
Total	%	100.0	100.0	100.0	100.0	100.0	100.0
	Unweighted N	4756.0	247.0	456.0	214.0	57.0	5730.0
	Weighted N	4654.4	269.8	506.4	244.7	64.7	5739.9
Observations		5730					
P		0.340					

**Table 6. HBSC 2013/14: Frequency of experiencing selected adverse physical symptoms by CED consumption**

Experience of physical health outcome		Headaches			Stomach ache			Sleep difficulties		
		Less than weekly or no CED	Weekly CED consumption	Total	Less than weekly or no CED	Weekly CED consumption	Total	Less than weekly or no CED	Weekly CED consumption	Total
About every day	%	4.8	7.7	5.6	2.3	3.3	2.6	11.8	17.9	13.5
	n	309.0	169.0	478.0	157.0	82.0	239.0	761.0	403.0	1164.0
More than once a week	%	12.0	14.4	12.7	6.1	10.3	7.3	11.3	14.0	12.1
	n	759.0	350.0	1109.0	404.0	250.0	654.0	727.0	315.0	1042.0
About every week	%	12.3	14.5	12.9	8.6	10.5	9.1	11.7	11.4	11.6
	n	819.0	345.0	1164.0	555.0	238.0	793.0	754.0	279.0	1033.0
About every month	%	24.5	22.9	24.1	33.2	30.4	32.4	17.3	14.6	16.5
	n	1617.0	555.0	2172.0	2166.0	727.0	2893.0	1111.0	346.0	1457.0
Rarely or never	%	46.5	40.4	44.7	49.8	45.5	48.6	48.0	42.1	46.3
	n	3047.0	938.0	3985.0	3252.0	1055.0	4307.0	3168.0	1008.0	4176.0
Total	%	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	n	6551.0	2357.0	8908.0	6534.0	2352.0	8886.0	6521.0	2351.0	8872.0
Observations		8908			8886			8872		
P		0.0000665			0.00000379			0.000000140		

**Table 7. HBSC 2013/14: Frequency of experiencing selected adverse mental health indicators by CED consumption**

Experience of mental health indicator		Low mood			Irritability		
		Less than weekly or no CED	Weekly CED consumption	Total	Less than weekly or no CED	Weekly CED consumption	Total
About every day	%	5.7	9.0	6.6	6.5	14.4	8.7
	n	361.0	202.0	563.0	400.0	326.0	726.0
More than once a week	%	9.2	11.3	9.8	11.5	16.4	12.9
	n	570.0	248.0	818.0	752.0	378.0	1130.0
About every week	%	10.0	10.4	10.1	14.2	15.3	14.5
	n	667.0	252.0	919.0	927.0	375.0	1302.0
About every month	%	19.9	19.9	19.9	24.3	20.7	23.2
	n	1264.0	479.0	1743.0	1589.0	482.0	2071.0
Rarely or never	%	55.2	49.4	53.5	43.6	33.3	40.7
	n	3662.0	1165.0	4827.0	2864.0	793.0	3657.0
Total	%	100.0	100.0	100.0	100.0	100.0	100.0
	n	6524.0	2346.0	8870.0	6532.0	2354.0	8886.0
Observations		8870			8886		
P		0.0000582			9.00e-13		

**Table 8. Smoking & Drinking Survey: Ever tried alcohol/smoking**

	Tried alcohol			Tried smoking		
	Less than a can a week or none	Weekly CED consumption	Total	Less than a can a week or none	Weekly CED consumption	Total
Never tried smoking or alcohol	71.1 3157.0	40.9 574.0	64.1 3731.0	89.6 3982.0	60.3 871.0	82.8 4853.0
Tried smoking or alcohol	28.9 1222.0	59.1 829.0	35.9 2051.0	10.4 448.0	39.7 560.0	17.2 1008.0
Total	100.0 4379.0	100.0 1403.0	100.0 5782.0	100.0 4430.0	100.0 1431.0	100.0 5861.0
Observations	5782			5861		
P	2.03e-38			8.90e-40		

**Table 9. Smoking & Drinking Survey: Frequency of Caffeinated Energy Drink use and Truancy/Exclusion (weighted column percentages and unweighted numbers)**

		No self-reported truancy/exclusion	Self-reported truancy/exclusion	Total
Never drink CED	Weighted %	34.4	9.1	30.3
	Unweighted N	1695.0	82.0	1777.0
Not in past week	Weighted %	39.8	32.9	38.6
	Unweighted N	1942.0	290.0	2232.0
Less than a can	Weighted %	7.3	8.4	7.4
	Unweighted N	363.0	80.0	443.0
One can or more	Weighted %	18.5	49.6	23.6
	Unweighted N	965.0	491.0	1456.0
Total	%	100.0	100.0	100.0
	Unweighted N	4965.0	943.0	5908.0
	Weighted N	4957.7	958.2	5915.8
Observations		5908		
P		<0.001		

Table 10: Characteristics of Latent Classes

Indicator	Class 1. Low psychological wellbeing	Class 2. High overall wellbeing	Class 3. Low educational wellbeing	Class 4. Low physical wellbeing	Class 5. Overall low wellbeing
High irritability	0.6573	0.083095	0.274775	0.376834	0.891296
Sleep difficulties	0.538183	0.127695	0.207435	0.538359	0.871775
Nervousness	0.615317	0.088042	0.032447	0.376788	0.86252
Dizziness	0.178066	0.026657	0.075396	0.413395	0.707369
Experience of Headaches	0.244619	0.071752	0.180905	0.735036	0.84878
Experience of Stomach aches	0.127576	0.022605	0.047883	0.437921	0.673524
Low mood	0.519551	0.015575	0.015091	0.242559	0.917237
Low life satisfaction	0.126226	0.010538	0.065964	0.009591	0.341628
School dislike	0.368151	0.071455	0.621453	0.210043	0.573324
Pressure of school work	0.571089	0.222751	0.41592	0.407456	0.676186
Low self-rated achievement	0.324202	0.119422	0.633349	0.159166	0.403711



**Table 11: Multinomial logistic regression predicting class membership – baseline Class 2. High overall wellbeing**

	RRR	95% CI		RRR	95% CI		RRR	95% CI		RRR	95% CI	
	Class 1. Low psychological wellbeing			Class 3. Low educational wellbeing			Class 4. Low physical wellbeing			Class 5. Overall low wellbeing		
Year Group (base: Year 7)												
Year 8	1.28572	1.002977	1.64817	1.452124	0.875115	2.409584	0.986307	0.791519	1.229029	1.409331	0.965243	2.057735
Year 9	1.416154	1.128039	1.777856	1.491797	0.844542	2.635107	0.994302	0.801465	1.233537	1.800065	1.325619	2.444317
Year 10	2.020809	1.576427	2.590457	2.411984	1.402504	4.148057	0.997234	0.751511	1.323303	2.630055	1.861807	3.71531
Year 11	2.064269	1.517007	2.808957	2.361716	1.405729	3.967837	0.93607	0.73362	1.194388	2.144747	1.473416	3.121956
CED consumption (base: Never/rarely)												
Less than 1 per week	0.965036	0.797677	1.167508	1.344917	0.95852	1.887078	1.10835	0.888725	1.38225	1.290336	1.053289	1.580731
1-4 days a week	1.294605	1.021821	1.640211	2.485422	1.811118	3.410778	1.483725	1.131736	1.94519	1.885862	1.461385	2.433634
5+ days	1.91105	1.420172	2.571599	4.881275	3.554216	6.703826	2.348545	1.625291	3.393648	4.170123	2.832193	6.140092
Gender (base: male)												
Female	1.585933	1.355324	1.85578	0.969258	0.733271	1.281193	2.311939	1.961229	2.725365	4.697456	3.815118	5.783857
Drank Alcohol (base: Never tried)												
Tried	1.615047	1.323237	1.97121	1.717131	1.234934	2.387609	1.930918	1.557508	2.393852	2.79476	2.256018	3.462156
Smoking (base: Never tried)												
Tried	2.194551	1.560746	3.085737	2.435214	1.605855	3.692901	1.548455	1.09376	2.192174	3.562749	2.589511	4.901768
Rurality (base: not rural)												
Rural	1.041792	0.792721	1.36912	1.217607	0.767494	1.931697	0.973454	0.768529	1.233021	1.115661	0.806361	1.543601
Family advantage score (base: high or average)												
Low family affluence	1.042671	0.774395	1.403888	1.352246	0.841548	2.172864	1.40543	1.002947	1.969428	1.333363	1.031025	1.724357
Constant	0.133172	0.106169	0.167042	0.034743	0.023869	0.05057	0.107602	0.083459	0.13873	0.021136	0.014685	0.030422

RRR=relative risk ratio, CI=confidence interval

## Up to half of kids worldwide and up to third of UK kids consume energy drinks weekly

*Consumption on 5+ days of the week linked to health and behavioural issues*

*Secondary data analysis helps fill evidence gap, but still can't distinguish cause from effect*

Up to half of children worldwide, and up to a third of children in the UK, consume energy drinks every week, with a tally on five or more days of the week associated with some health and behavioural issues, finds research published in the open access journal **BMJ Open**.

But while this secondary analysis of the available data helps fill the evidence gap, most of the data are derived from surveys, making it impossible to distinguish cause from effect, caution the researchers.

Energy drinks are marketed as reducing tiredness and improving concentration as well as boosting energy. An average 250 ml energy drink contains a similar amount of caffeine to a 60 ml espresso.

Many of these drinks also contain other active ingredients, such as guarana and taurine (stimulants) and sugar, although sugar-free options are also available.

In 2018, the UK government ran a consultation on banning the sale of these drinks to children, but as only two UK studies were identified among the available evidence, additional UK data was sought, and a secondary analysis of relevant data was carried out to ensure relevance to UK policy.

For this, the researchers wanted to find out what type and how many energy drinks UK teens were getting through. And they wanted to explore the potential impact on young people's physical and mental health, and behaviour.

In July 2021 the researchers updated their original trawl of relevant research from 9 databases carried out in May 2018.

Two further systematic reviews were added to the original 13, covering a total of 74 studies, published in English since 2013: 6 of these 15 reviews reported on prevalence and 14 reported on associations between consumption and health or behaviour.

The additional analysis included data representative of the UK or one of the devolved nations, including information on the levels and patterns of energy drink consumption among children and the potential effects on cardiovascular health, mental health, neurological conditions, academic achievement, substance misuse, or sleep.

The systematic review data revealed that, worldwide, between 13% and 67% of children had consumed energy drinks in the preceding year.

Analysis of the additional UK data indicated that between 3% and 32% of children across the UK consumed energy drinks on at least one day of the week, with no difference by ethnic background.

Frequent consumption, defined as drinking an energy drink on 5 or more days of the week, was associated with poor mental and physical health, and overall poor wellbeing compared with those who didn't consume energy drinks.

Evidence from the reviews indicated consistent associations between energy drinks and self-harm, suicide, hyperactivity, academic performance and school attendance.

Evidence from both the reviews and UK data suggested that boys drank more than girls, with consumption rising in tandem with age; and that consumption was associated with more headaches, sleep problems, alcohol use, smoking, irritability, and school exclusion.

But the application of a quality grading system (GRADE) suggests that the evidence is weak. This is because most of the data for the reviews came from cross-sectional surveys, while none of the additional data included long term information.

And it was impossible to pool the survey data from the reviews because of the differences in design and measures reported.

"These data support the idea that there is a link between drinking [caffeinated energy drinks] and poorer health and behaviour in children, although the cause is unclear," write the researchers.

They conclude: "Based on a comprehensive overview of available systematic reviews, we conclude that up to half of children, worldwide, drink [caffeinated energy drinks] weekly or monthly, and based on the dataset analysis, up to a third of UK children do so."

They add: "There is weak but consistent evidence, from reviews and UK datasets, that poorer health and wellbeing is found in children who drink [caffeinated energy drinks]. In the absence of [randomised controlled trials], which are unlikely to be ethical, longitudinal studies could provide stronger evidence."