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Review Paper

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

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ABSTRACT

Objective: To update an earlier review, published in 2016, on the health and other outcomes associated with children and young people's consumption of energy drinks (EDs).
Study design: Review article.
Systematic review: Systematic searches of nine databases (ASSIA, CINAHL, Cochrane Library, DARE, Embase, ERIC, MEDLINE, PsycINFO and Web of Science) retrieved original articles reporting the effects of EDs experienced by children and young people up to the age of 21 years. Searches were restricted by publication dates (January 2016 to July 2022) and language (English). Studies assessed as being weak were excluded from the review. Included studies underwent narrative synthesis.
Results: A total of 57 studies were included. Boys consumed EDs more than girls. Many studies reported a strong positive association between ED consumption and smoking, alcohol use, binge drinking, other substance use and the intentions to initiate these behaviours. Sensation-seeking and delinquent behaviours were positively associated with ED consumption, as were short sleep duration, poor sleep quality and low academic performance. Additional health effects noted in the updated review included increased risk of suicide, psychological distress, attention-deficit hyperactivity disorder symptoms, depressive and panic behaviours, allergic diseases, insulin resistance, dental caries and erosive tooth wear.
Conclusions: This review adds to the growing evidence that ED consumption by children and young people is associated with numerous adverse physical and mental health outcomes. Where feasible and ethical, additional longitudinal studies are required to ascertain causality. The precautionary principle should be considered in regulatory policy and restriction of ED sales to this population.
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Introduction

Energy drinks (EDs) are non-alcoholic beverages containing high amounts of caffeine (≥150 mg/l) and sugar in addition to other stimulants such as taurine, ginseng and guarana.[1,2] The caffeine content of EDs varies between 50 mg and 505 mg per serving compared to 90 mg in 250 ml coffee, 50 mg in 250 ml tea and 34 mg in 500 ml of cola.[13,14] Excessive intake of caffeine can lead to caffeine intoxication and dependence,[15] with symptoms including headache, insomnia, restlessness, anxiety, gastrointestinal disturbances and cardiovascular symptoms.[16] Many EDs are also high in sugar (9–13 g/100 ml) and are classified as sugar-sweetened beverages (SSBs). Excessive sugar consumption is associated with weight gain, obesity, type 2 diabetes and dental erosion.[17–20] The effects of EDs are attributed to caffeine, caffeine-like additives, or other ingredients like taurine that may interact with caffeine.[3,4] Energy shots are smaller in volume but often contain at least the same amount of caffeine as EDs.[5] Consumption of EDs has increased rapidly since their inception in 1987.[3,6] The global ED market was worth $45.80 billion in 2020 and is projected to grow at an annual rate of 8.2% to reach $108.40 billion by 2031.[7]

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A 2013 study of 37,500 children and adolescents in 16 European countries found that 18% of children (3–10 years) and 68% of adolescents (10–18 years) consumed EDs in the previous year.[8] Studies have reported that between 12% and 35% of children and young adults consume EDs at least once per week.[9–12]

A number of countries have attempted to regulate EDs, including bans on sales to under 18s (Lithuania and Latvia) and the restriction of sales to pharmacies (see Table 1). In 2018, Jamie Oliver launched the EDs are #NotForChildren Campaign,[21] resulting in many UK supermarkets imposing a voluntary ban on sales to under 16s.[22] The UK government ran a consultation on ending the sale of EDs to children in England and also proposed this in their 2019 green paper.[23] While 93% of respondents to the consultation supported restricting sales to under 16s,[23] there has been no further action. In 2022, the devolved government in Wales launched its own consultation to ban the sales of EDs to under 16s.[24]

Growing evidence suggests that excessive ED consumption is associated with adverse effects in children and young people.[2,31–40] Systematic reviews have found that ED use was associated with many health-damaging outcomes and risky behaviours.[2,34,36–40] The aim of this review was to update a review conducted in 2016 by two of the authors (AAL and SV),[34] given the ongoing public and policy concerns relating to ED consumption by children.

Methods

This systematic review was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement.[41] The protocol was registered with PROSPERO (CRD42021255484). Table 1 supplementary material shows the PICO (**P**opulation, **I**ntervention, **C**omparator and **O**utcome) framework used to formulate the research question and search strategy.

Search methods

Nine databases (ASSIA, CINAHL, Cochrane Library, DARE, Embase, ERIC, MEDLINE, PsycINFO and Web of Science) were systematically searched using tailored strategies (Table 2 supplementary material).

In order to update the previous review,[34] searches were restricted by publication date (January 2016–July 2022) and by English language. No restrictions were applied on country, gender or race/ethnicity.

Inclusion and exclusion criteria

Original articles reporting the effects of ED consumption in children and young people up to the age of 21 years were included. Articles focused on individual ED ingredients, isotonic sports drinks or other beverages, involving participants over 21 years, animal studies, editorials, opinion papers, conference abstracts, case reports, systematic reviews, meta-analyses, and studies not published in English were excluded.

Exposure and outcomes

The exposure was the consumption of EDs (as defined by the study authors, including lifetime, occasional and regular intake) and the control, where relevant, was the absence of ED consumption. Outcome measures were any health, well-being, social, behavioural and educational outcomes, ED consumption patterns and attitudes towards EDs, in line with the earlier review.[34]

Study selection

Results obtained from the database searches were exported into EndNote 20 and duplicates removed. Two reviewers (CA and AVG) independently screened titles and abstracts, with a random 10% of the sample independently screened by a third reviewer (AAL). The same process was followed for screening full texts of these papers against the inclusion and exclusion criteria. The database searches were performed by CA, and specificity and sensitivity were checked by ensuring five (previously identified) key papers[44,46,60,72,92] were returned in the search results.

Quality assessment

Quality assessment was completed using the Critical Appraisal Skills Programme (CASP) checklist for qualitative studies and the Effective Public Health Practice Project (EPHPP) Quality Assessment Tool for Quantitative Studies.[42,43] Studies were rated as strong, moderate or weak; those rated as 'weak' were excluded.

Data extraction

Data extraction and quality assessment were carried out simultaneously and independently using a template based on one used in the previous review.

Data synthesis

Data from the included studies were grouped by study design, summarised descriptively, and a narrative synthesis conducted.

Results

Search results

Searches located 1404 articles (Fig. 1); 105 studies met the inclusion criteria but 48 of these were excluded due to being rated as 'weak'. Fifty-seven studies were included.

Table 1
ED regulations in other countries.

Countries	Actions
Lithuania	Banned the sale of EDs to under 18s in 2014.[25]
Latvia	Banned the sales of EDs to under 18s in 2016.[25]
Turkey	Turkish Food Codex Regulation ED Communique banned the sales of EDs to under 18s in 2018.[26,27]
Sweden	Sales of EDs to children <15 years are banned and the sales of some products are restricted to pharmacies.[28]
Norway	Prior to 2009, EDs were regulated like pharmaceuticals and could not legally be sold in grocery stores due to their high caffeine content.[25] Currently, there are no regulations that prevent children and adolescents from buying EDs.[25]
Spain	Spanish Agency for Food Safety and Nutrition (AESAN) recommended that under 18s, pregnant and breastfeeding mothers avoid ED consumption.[29]
USA	No age restrictions although American Academy of Paediatrics, American College of Sports Medicine and the American Heart Association have discouraged ED use among children, adolescents and young people.[30]

Characteristics of included studies

Tables 3–7 supplementary material show the characteristics of the included studies. There were 42 cross-sectional, six experimental, seven longitudinal, one retrospective and one qualitative studies. More than half reported the frequency of ED consumption. Seven studies reported the use of alcohol mixed with energy drinks (AmED). Studies were conducted in North America (n = 16), Europe and Central Asia (n = 24), East Asia and Pacific (n = 7) and Middle East and North Africa (n = 8), with two studies involving multiple countries[44,45]. The overall sample size was 1,287,682 participants (range: 16 to 278,891) aged between nine and 21 years. Most papers (n = 49) were rated 'moderate', while eight papers were rated 'strong' in quality.

There were many commonalities with the findings of the previous review.[34] For example, both reviews identified that boys were more likely to consume EDs than girls and that branding and marketing were reported to be key influencing factors. In both, ED consumption was found to be associated with health-damaging behaviours, as well as headaches and sleeping problems. The previous review also found ED consumption to be associated with stomach ache, an outcome that was not identified in the updated review. However, several additional outcomes were identified in

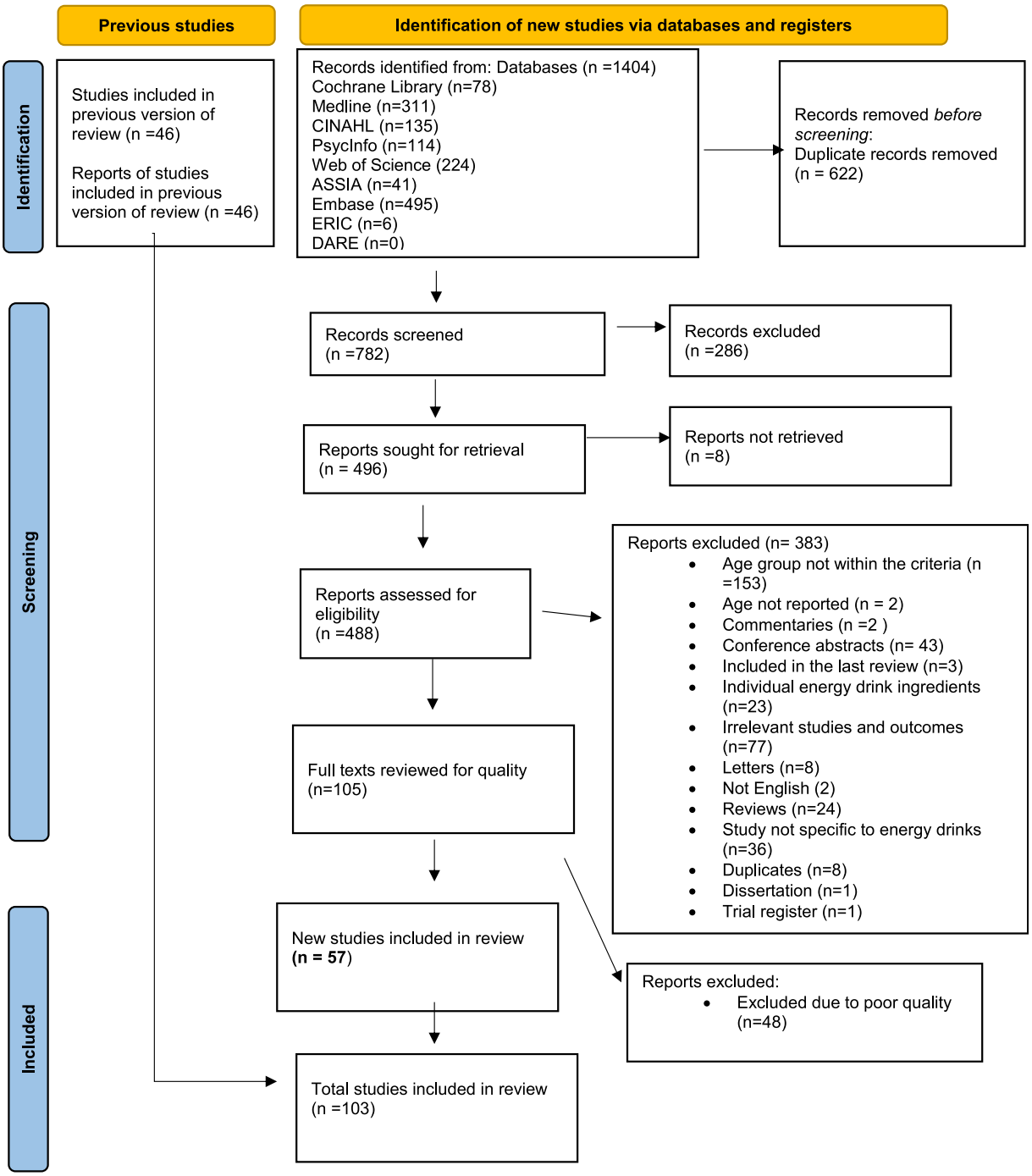

Fig. 1. Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) Flow Chart. Colours should be used for all figures in print.

this review. To avoid repetition, the remainder of the results section focuses primarily on these novel findings. Table 2 compares findings from the current and previous reviews.

Health-related behaviours

As in the previous review, smoking, alcohol use, binge drinking, substance use and intention to initiate these behaviours were found to be positively associated with frequent consumption of EDs.[10,46–57] A longitudinal study[56] reported that increased ED consumption increased the odds of current smoking and vaping use, and also increased smoking and vaping initiation one year later. Vaping use was not identified in the previous review.

A positive link between AmED and substance use was noted.[58–62] A retrospective study[62] indicated that AmED users were more likely to report poor grades, delinquent behaviour, substance use-related unsafe driving, public intoxication, and drug use than those who consume EDs without alcohol.

Consumption of EDs without alcohol was associated with sensation-seeking,[63] norm-breaking behaviours (e.g. truancy)[64] and less healthy lifestyles. ED consumers were significantly more likely than non-consumers to engage in unsafe vehicle use, violent behaviours, unsafe sex, binge drinking, cigarette use and disordered eating.[10] Use of EDs and AmEDs was positively associated with going out with friends for fun, experiencing physical fights, accidents or injury and being involved in driving accidents.[47] ED consumers were more likely to consume energy-dense fast foods, snack foods, other SSBs and skip breakfast regularly.[63,65–68]

Some studies found an inverse association between physical activity levels and ED consumption.[57,69,70] Conversely, one study[71] reported that regular ED intake was more frequent in boys with higher physical activity levels than among those with lower levels.

Of the 10 studies exploring ED intake and educational outcomes, most found that ED consumers were more likely to report low academic performance and achievement.[12,47,57,61–63,65,72,73] Those who combined alcohol and ED were at higher risk of negative outcomes and behaviours (e.g. bullying) compared with consumers of alcohol only and ED only.[61] In contrast, one cross-sectional study showed a positive relationship between high school performance and ED consumption.[50]

Effects of EDs on sleep patterns were reported by 13 studies.[44,64,66–68,71,72,74–79] Short sleep duration and poor sleep quality were consistently associated with increased frequency of ED consumption.[64,66–68,72,74,76–79]

Longitudinal analysis found that ED consumers had higher average body mass indexes (BMIs) than non-consumers.[63] Conversely, Utter et al.[10] reported no association between ED consumption and BMI. Lee and Lee[80] found that the prevalence of all unhealthy weight control behaviours (one-food diets, fasting, diet pill use, purging) increased as ED intake increased. Another study reported that ED consumers had increased central obesity and fasting blood sugar and were significantly at increased risk of metabolic syndrome than non-consumers.[81]

Three randomised controlled trials (RCTs) investigated the effects of ED consumption on cardiovascular function in the same cohort of healthy adolescents.[82–84] Acute ingestion of ED was associated with a significantly increased number of supraventricular extrasystoles (SVES) and a decrease in heart rate,[83] highlighting the negative effect of ED consumption on heart rhythm.[83] ED consumption was also associated with increased arterial

Table 2
Comparison of the present review with the 2016 original review.

	Original review	This review
Number of articles located; number of papers included; study designs	Total of 520 articles identified with 410 articles remaining after the removal of duplicates; 46 included in the review. 31 cross-sectional studies 4 longitudinal studies 4 retrospective studies 3 experimental studies 4 qualitative or mixed method studies	Total of 1404 articles identified with 782 articles remaining after the removal of duplicates; 57 included in the review. 42 cross-sectional studies 7 longitudinal studies 1 retrospective study 6 experimental studies 1 qualitative study
Consumption patterns	Boys and older adolescents were more likely to consume EDs. Being underweight or obese, being from a single parent family, receiving free school meals, having special educational needs and higher spending money were linked with higher ED consumption. Those with higher academic averages, higher sense of coherence, higher levels of parental monitoring and more educated parents were less likely to use EDs.	Boys and older adolescents were more likely to consume EDs. Low parental education, blended/lone parenting, parents' continuous dieting, parents' continuous criticism of past mistakes, having higher weekly spending money, ED use by friends or peers and living in rural areas were linked with higher ED consumption.
Health-related behaviours associated with ED consumption	Alcohol and binge drinking, smoking or susceptibility to smoking and other substance use. Also, sensation-seeking, self-destructive behaviour, problems with behavioural regulation and metacognitive skills and health-damaging lifestyle behaviours.	Smoking, alcohol use, binge drinking, other substance use and the intentions to initiate these behaviours. More likely to engage in delinquent behaviours, unsafe vehicle use, violent behaviours, unsafe sex, truancy, physical fighting, sensation-seeking Poor lifestyle including frequent skipping of breakfast and eating energy-dense fast foods, snack foods and other SSBs.
Detrimental health effects associated with ED consumption	Headache, sleeping problems, irritation, tiredness, fatigue, stomach aches, hyperactivity. Cardiac rhythm disturbances, hypertension and hyperthermia.	Palpitation, insomnia, frequent urination, headache and anxiety. Increased risk of suicidality, suicide attempts or thoughts, stress, psychological distress, depressive and panic symptoms, inattention and conduct disorder. Asthma, allergic rhinitis, atopic dermatitis, insulin resistance, dental caries/erosive tooth wear, short sleep duration and poor sleep quality, poor academic performance. Increased arterial stiffness, increased systolic and diastolic blood pressure, increased number of supraventricular extrasystoles and a decreased heart rate.
Enhanced sports performance	Limited evidence (coupled with increased risk of dehydration)	Limited evidence
Reasons for consumption	Taste and energy seeking	Taste, performance enhancement, curiosity,
Influences on use	Marketing and branding, peer influences, parents, accessibility	Marketing and branding, social/peer influences, price, ease of access

stiffness[82] and significantly increased systolic blood pressure (SBP) and diastolic blood pressure (DBP).[84]

ED consumers reported heart palpitations, frequent urination and anxiety, which were not identified in the 2016 review (along with insomnia and headaches, which were identified in the previous review).[76,34]

Other novel findings include the frequency of ED consumption being related to prevalence of dental caries[85] and erosive tooth wear.[45] Frequent ED consumption (more than seven times per week) was also positively associated with asthma, allergic rhinitis and atopic dermatitis.[88] Individuals recently diagnosed with atopic dermatitis were significantly more likely to consume EDs, relative to those who were previously diagnosed with atopic dermatitis or a control group.[89]

Various negative mental outcomes were found to be linked with ED consumption.[10,50,72,86,87] Frequent ED intake was associated with suicide attempts and severe stress;[72] there were also higher rates of suicide ideation and attempts with ED intake greater than once per day.[50] ED consumption was linked with increased moderate-to-high psychological distress, suicide thoughts and attempts.[86] Longitudinal analysis reported that ED consumption was related to increased ADHD inattention, conduct disorder, depressive and panic symptoms.[87] Regular ED consumption was also associated with emotional difficulties and lower levels of well-being.[10,88,89] An RCT found that energy shots induced insulin resistance in adolescents compared to the control group.[90]

Impact on sports performance

Two RCTs by the same lead author reported a positive impact of EDs on sports performance.[91,93] One involved 16 youth female water polo players and found that the intervention group experienced an increase in some performance indicators but no change in others after consuming an ED. The second trial involved 36 elite female swimmers and found ED consumption to be ineffective on a range of performance indicators, with the exception of 100m crawl time.

Attitudes towards, influences on ED consumption

In addition to taste and energy seeking,[34] reasons given for ED consumption were social and peer influence,[66,92] performance enhancement,[66,76] curiosity,[76] price, ease of access, branding and marketing.[92,66] Adolescents who had more positive perceptions of EDs (e.g. they improve alertness, athletic performance, concentration) were more likely to use EDs.[75]

Discussion

This study adds to the evidence that ED consumption in children and young people is associated with detrimental health, educational and social effects, as well as health-damaging behaviours. It also highlights an increase in the volume of research in this area.

Reported outcomes were positive associations between ED consumption and risky behaviours such as smoking, alcohol use, binge drinking, other substance use and the intentions to initiate these behaviours. ED users were significantly more likely to engage in sensation-seeking and delinquent behaviours such as unsafe vehicle use, violence, unsafe sex, truancy and bullying. Nine studies demonstrated a relationship between higher ED consumption and lower academic performance. Short sleep duration and poor sleep quality were consistently linked with increased frequency of ED consumption. ED consumers were more likely to consume energy-dense fast foods, snack foods, other SSBs and skipped breakfast regularly.

Evidence from RCTs[82–84] demonstrated increased arterial stiffness, increased SBP and DBP, increased number of SVES and a decreased heart rate after ED consumption. Although limited by small sample sizes, the findings highlight the cardiovascular risk of ED use in children and young people. While two RCTs reported a consistent association of ED ingestion with some aspects of athletic performance, both studies were limited by sample size and involved females only[91,93]

This review identified additional mental and physical health effects that were associated with ED consumption which were not reported in the earlier review.[34] Frequent ED consumption was associated with mental health outcomes including increased anxiety, risk of suicidality, stress, depressive and panic symptoms, emotional difficulties, ADHD inattention and conduct disorder. Additional physical health effects included asthma, allergic rhinitis, atopic dermatitis, insulin resistance, dental caries, and erosive tooth wear. ED consumers also reported palpitations, insomnia and frequent urination.

The findings of this review are consistent with earlier reviews,[34,37–40] including boys consuming more than girls;[34,37,39] ED use being associated with many adverse outcomes and risky behaviours;[34,37] and increased likelihood of anxiety, depression, impulsivity, poor academic performance and sleep problems.[37,39] In addition to sensation-seeking behaviour, irritability, suicide ideation, plans and attempts,[38,40] polysubstance use, violent and risky behaviours, poor dietary habits[38] and headaches, sleep problems, alcohol use, smoking, irritability and school exclusion.[39] Adolescents with lower grades, low parental monitoring, or bad peer influences have been shown to be more likely to consume EDs.[40] In this and other reviews, taste and energy-seeking were the main drivers of ED use, and frequent ED consumption was associated with low psychological, physical, educational and overall well-being.[39]

A plausible mechanism for the health and behavioural effects of EDs has been attributed to caffeine.[94,95] Caffeine, in combination with sugar and other ingredients with stimulant properties, could have a significant impact on the overall health of children and young people.[94] The associations could be mediated by poor sleep patterns and unhealthy dietary habits, including skipping breakfast and eating unhealthy foods.[65,67,72,96] Furthermore, the small number of longitudinal analyses.

As the majority of studies (75%) included in the review were cross-sectional, it is difficult to determine causation. While this underlines for the lack of experimental and longitudinal studies, it also suggests that policymakers should adopt the 'precautionary principle' in order to prevent harm to children and young people.[25,97] There is evidence of a dose–response effect, providing further justification for efforts to limit the consumption of EDs by children.

Strengths of this review included the robust search strategy and searching multiple databases. Searches were not restricted to country or sex. Screening, data extraction and quality assessment were completed by two reviewers independently.

This review was limited by the quality and design of the included studies. Most were cross-sectional studies and rated 'moderate' in quality, while a large number ($n = 48$) were excluded for being 'weak'. Many papers were excluded based on the participants' ages not being well defined. Another limitation is that the data were summarised qualitatively rather than statistically, as given the variation in studies, this was not possible.

Experimental studies to ascertain causality have both ethical and feasibility issues. Future research could use longitudinal study designs, where feasible and ethical, to provide further insight. Further qualitative studies would provide understanding into the behaviours of children and young people. Given the evidence of ED-

related harm to the physical and mental health of children and young people and the lack of nutritional or functional value of these products, we suggest policymakers apply the precautionary principle and consider banning the sales of these products to children.

Conclusion

This paper updates the original 2016 review[34] and expands the evidence base that consumption of EDs by children and young people could impact on their physical, mental, behavioural, educational and overall health.

Despite the limitations of this review, the results strengthen the existing evidence on the adverse effects of ED consumption and provide evidence-based information for stakeholders.

The findings emphasise the need for regulatory policy and restriction of ED consumption among children and young people, including banning the sales of EDs and limiting direct advertising to younger age groups.

Author statements

Ethical approval

No ethical approval was required.

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Competing interest

None declared.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.puhe.2023.08.024.

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