

## Consumption Patterns of Energy Drinks in University Students: a Systematic Review and Meta-analysis

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### Highlights

- University students commonly use energy drinks for study or sport aims
- Adverse effects, mainly sleep and cardiovascular disorders, are reported in relation to energy drink consumption
- The consumption of energy drinks is strongly related to alcohol, tobacco and drugs use
- High-risk groups of energy drink consumers should be early identified to prevent associated health outcomes.

Journal Pre-proof

*Systematic Review***Consumption Patterns of Energy Drinks in University Students: a Systematic Review and Meta-analysis**

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**Abstract:** Energy Drinks (EDs) use is promoted to stimulate mental and/or physical activity, and over the years their popularity increased, especially among young people. However, the use of EDs is often improper and can induce some adverse effects for human health. The purpose of this systematic review and meta-analysis was to analyse the literature to characterize prevalence of ED consumption and motivations to use among undergraduate students. Furthermore, adverse effects and health-related behaviors associated to ED use were explored. This systematic review was carried out according to the PRISMA Statement and the databases PubMed, Scopus and Web of Science were used for data research. 71 articles published between 2007 and 2021 met the inclusion criteria and were included in the review. The estimated overall prevalence of ED consumption was 42.9% in undergraduate students (95% CI:42.5%-43.3%), with significant heterogeneity among studies (Q test:  $p < 0.001$ ;  $I^2 = 99.4\%$ ). The main reasons for their use were engagement in study, projects or examinations, to stay awake or alert, physical activity/sport engagement. Sleep disturbance and increased heart rate or blood pressure were the most commonly reported adverse effects. ED consumption was frequently associated with alcohol use and smoking. These findings suggest that inappropriate use of EDs and related unhealthy behaviors should be early identified and addressed through effective educational interventions.

**Keywords:** Energy drink; Undergraduates; University students; Consumption; Adverse effects

## 1. INTRODUCTION

Nowadays, the use of Energy Drinks (EDs) is promoted to increase energy, concentration, athletic performance, and metabolism and to stimulate mental activity and alertness through a combination of sugar, caffeine, amino acids, like taurine, and herbal supplements, like ginseng. [1] Caffeine (1,3,7-trimethylxanthine) is the main ingredient of EDs, with a range of 50 to 550 mg per can or bottle. [1] EDs contain higher doses of this stimulant than traditional caffeinated beverages. [2, 3] In addition, they contain other potentially active ingredients, such as taurine or sugar, in higher concentrations than other soft drinks, even if some sugar-free options are available. [4, 5] Both sugar and caffeine have been shown to determine the most important metabolic effects, with controversial physical and cognitive effects. [6, 7] In particular, acute caffeine consumption reduces insulin sensitivity [8] and increases mean arterial blood pressure; [9] central nervous system, cardiovascular, gastrointestinal, and renal dysfunction have been associated with chronic caffeine ingestion. [10] This is of particular concern for human health considering that an average of 250 mL of a typical ED contains 80 mg of caffeine, which is a similar amount to a 60 mL espresso, while the European Food Safety Authority (EFSA) proposes a safe level of 3 and 5.7 mg of caffeine per kg of body weight per day respectively for children/adolescents and healthy adults. [11]

Besides, since the removal of caffeine from the list of banned substances by the World Anti-doping Agency in 2004, athletes can use caffeine foods and caffeine-containing dietary supplements without contravening any anti-doping rule [12]. Additionally, caffeine is a socially accepted drug, and its performance-enhancing properties have been recently endorsed by international sports organizations such as the International Olympic Committee. [13]

Since 1997, year of debut of the first Energy Drinks company, their popularity increased and nowadays hundreds of EDs are marketed worldwide, with caffeine concentrations ranging from 20 to 50 mg/100 mL. [14] The main target of these industries are adolescents and young adults and 50% of college students have been estimated to be EDs users, influenced by aggressive and widespread advertising campaigns. [15, 16] Indeed, it is not surprising that the undergraduate population is the most exposed as it is susceptible to high levels of stress related to study commitments and it is the main consumer of caffeine. [17] Even though in low doses (already at 12,5 mg) EDs have some benefits on cognitive performance, concentration and mood [18] and its use is justified in the university student population as a way to stay awake, increase energy levels, boost performance during physical exercise and remain concentrated while studying, it can lead to

health damages depending both on the dose ingested and the individual susceptibility. [19-21] In particular, scientific evidence showed in university students a strong association between ED consumption and risk-taking behaviors, such as mixing EDs with alcohol, especially at parties, [19, 21, 22] and smoking tobacco and cannabis. [23] Further, an excessive intake of caffeine through ED consumption is generally related to irritability, anxiety, restlessness, insomnia, gastrointestinal upsets, tremors, tachycardia, psychomotor agitation. [21, 24-26] This evidence is of high interest for public health considering the high prevalence of ED consumers, especially among youths. In fact, the EFSA report on ED consumption across 16 European Union countries showed that 68% of adolescents (10-18 years old), 30% of adults (18-65 years old), and 18% of children (3-10 years old) had consumed an ED at least once in the previous year. The average consumption was 2 liters a month in adults, 2.1 in adolescents, and 0.49 in children. [26]

The risk behaviors and the negative health outcomes linked to the ED consumption together with the high prevalence of their use highlight the need for an appropriate process of assessment and management of this phenomenon, especially in high-risk groups such as university students. The first step of this process is to trace an epidemiological picture on this issue. Indeed, several surveys have been performed in different countries to evaluate the prevalence of ED consumption, the motivations for their use and the negative outcomes; however, a systematic review of the scientific literature is lacking. The purpose of the present systematic review and meta-analysis was to analyze the available literature in order to explore EDs consumption and motivations to use among undergraduate students. Furthermore, adverse effects and health-related behaviors associated to EDs use in this population group were explored.

## **2. MATERIALS AND METHODS**

### **2.1. Selection Protocol and Search Strategy**

The present systematic review was conducted according to the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) guidelines. [27] The protocol was registered in PROSPERO (reference number CRD42021281219).

The review question was framed using PICOS framework and the following eligibility criteria: (a) Population: all genders university students; (b) Intervention: energy drink use in everyday life; (c) Comparison: age- and condition-matched control group; (d) Outcome: understand if consumption of energy

drinks has effects on health, daily habits and physical and/or mental activity; (e) Study: cross-sectional studies. We considered a university student to be a student enrolled in a college or university. Typically, the age of university students ranges from 18 to 24, but in some of the studies examined there were no age limits for the enrolment or the end of the university course and, thus, also older students were included in the review.

Three electronic databases (PubMed, Scopus and Web of Science) were interrogated using the following terms: "energy drink" AND consumption AND ("university students" OR "college students" OR "undergraduate students").

The search on PubMed was carried out by title, abstract, and MeSH terms; the search on Scopus and Web of Science included topic by title, abstract and keywords. The search was performed from 9<sup>th</sup> to 17<sup>th</sup> September 2021.

## **2.2. Inclusion and Exclusion Criteria**

This review was focused on university students' ED consumption habits. Consequently, studies were considered eligible if they reported data about ED consumption of university students, independently by their gender and age. All the studies which included individuals who were not university students or regarded the consumption of other dietary supplements than EDs were excluded. We also excluded studies reporting only the consumption of EDs mixed with alcohol or other substances. Only articles presenting observational studies were considered eligible. Clinical trials, experimental studies, reviews, meta-analysis, case studies, proceedings, qualitative studies, editorials, commentary studies and any other type were excluded. Reviews and meta-analyses were examined to identify further articles in their references. We included only articles published in English language, from the inception to September 17<sup>th</sup> 2021.

Titles and abstracts acquired from the three databases were transferred to the reference site Covidence—Better systematic review management for relevance assessment process. The next step was screening by title and abstract the potentially eligible studies, following the inclusion criteria said before; the screening was conducted by five authors (F.G., C.P., F.V., D.M., A.D.G.) independently. Then, full-texts were read independently by the same five authors (F.G., C.P., F.V., D.M., A.D.G.) with a later discussion about their inclusion in the review. Disagreements were achieved by consensus among the authors.

### 2.3. Data Extraction Process and Quality Assessment

A specific set of categories were chosen with consensus of all authors, and the extracted data were arranged into tables: bibliographic information like author, year, country, sample size, study subject/population with age, gender and ethnicity, and for the results, the following outcomes: ED consumption estimate, associated factors, motivation and adverse effects due to ED consumption.

The quality assessment was performed by the use of the tool NOS – Newcastle-Ottawa Quality Assessment Scale – adapted from cohort and case control studies to perform a quality assessment for cross-sectional studies. With the support of this scale an overall rating of “poor,” “fair,” or “good” quality was assigned to each eligible article according to the proportion of criteria met, as follows: Good Quality: if all criteria met (low risk of bias); Fair Quality: if 1 criteria not met or 2 criteria unclear, and the assessment that this was unlikely to have biased the outcome, and there is no known important limitation that could invalidate the results (moderate risk of bias); Poor Quality: If 1 criteria not met or 2 criteria unclear, and the assessment that this was likely to have biased the outcome, and there are important limitations that could invalidate the results; 2 or more criteria not met (high risk of bias). Five authors (F.G., C.P., F.V., D.M., A.D.G.) independently assigned a score to each study, and disagreements were settled by consensus among all the authors.

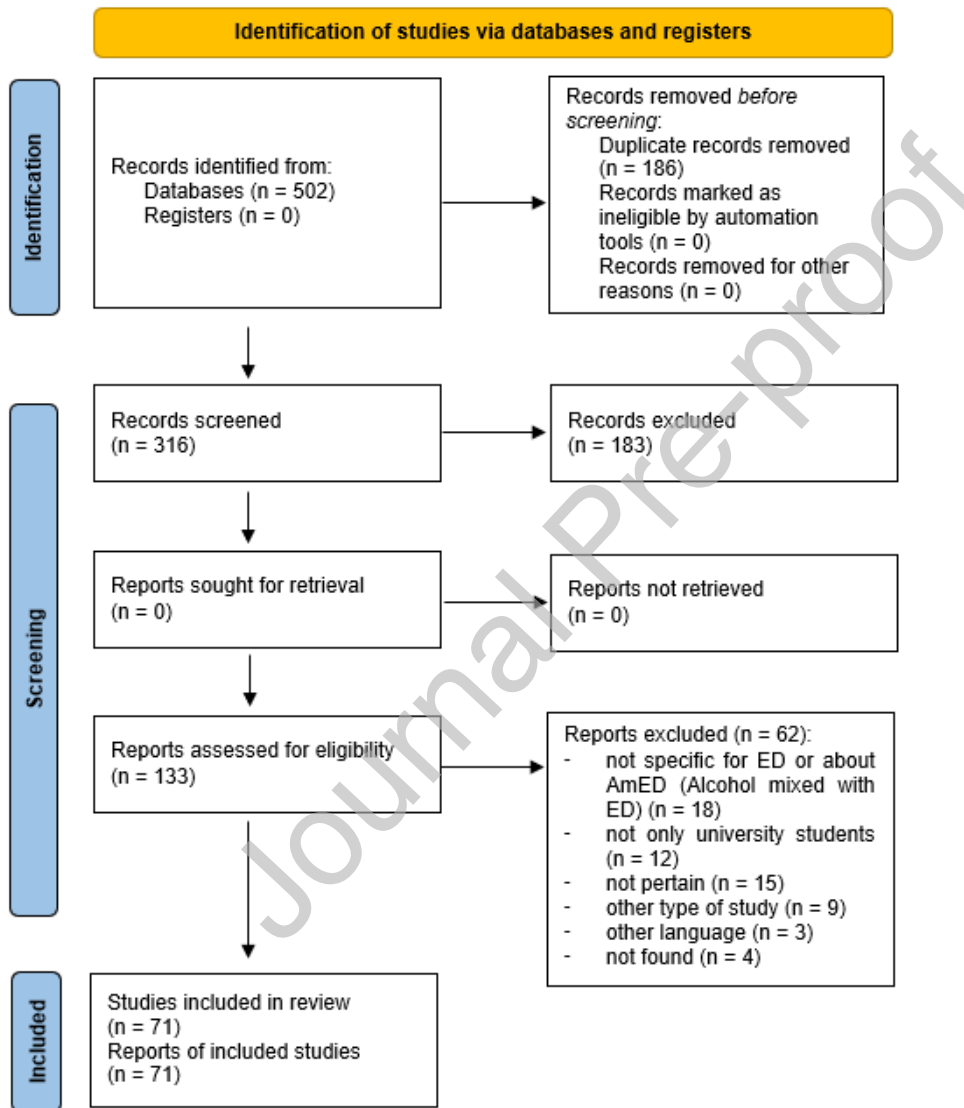
### 2.4. Statistical analysis

Meta-analysis and statistical elaborations were performed using Comprehensive Meta Analysis 4.0 (Biostat, Englewood, NJ, USA). The prevalence of ED consumption and 95% CI were extracted for each study.  $I^2$  statistic test was used to evaluate the heterogeneity of selected studies and using the classical measure of heterogeneity is Cochran's Q (Hedges Q statistic). The thresholds used for the interpretation of  $I^2$  were as follows: <25%, low heterogeneity; <50%, moderate heterogeneity; and >75%, high heterogeneity. [28] In order to assess the publication bias, due to the high volume of samples included, the Egger's test and Funnel plot were performed. [29] Meta-regression and subgroup analyses were performed to explore the sources of heterogeneity expected in meta-analyses of cross-sectional studies. [28-32] For meta-regression analysis, the sample sizes, the gender, the age, the publication years, the methodological quality of the study and WHO Regions origin (European Region - EUR, African Region - AFR, Region of the Americas - AMR, South-East Asia Region - SEAR, Eastern Mediterranean Region - EMR, Western Pacific Region – WPR) of studies were considered.



### 3. RESULTS

Figure 1 shows the steps of the study selection process for the systematic review, following the PRISMA statement. [27]



**Figure 1.** Flow-chart of search strategy.

In total, 502 studies were recovered from all searched databases and, after removing the duplicates, 317 articles were left for the following steps. Out of the remaining studies, 183 were deleted after analysing the

title and abstract. Then, the full texts of 134 articles were checked and evaluated considering inclusion/exclusion criteria. After the evaluation, 61 articles were excluded on the basis of the exclusion criteria.

Finally, 71 articles met the inclusion criteria and were included in the analysis (Tables 1 and 2). [16, 17, 21, 33-99]

**Table 1.** Characteristics of the samples and main results related to Energy Drink (EDs) patterns of consumption in the selected studies.

<b>Sample size Age (mean value <math>\pm</math> SD and/or range) Gender (%)</b>	<b>ED consumption estimate</b>	<b>Adverse effects</b>
404 20.7 (17-28 years) 62% M, 38% F	52.4% consumed EDs; consumers were mainly males ( $p=0.001$ ), and those who were more elderly ( $p=0.001$ )	Arrhythmias (62.6%) insomnia (16.4%), increased urination (13.3%), restlessness (8.7%)
546 18-28 years 31% M, 69% F	29.3% consumed ED; 73.1% of these consumed EDs 1-2 times/week	Elevated heartbeat (38.5%), frequent urination (19.2%), 49 participants experienced jolt-and-crash symptoms and signs (11.5%), insomnia (11.5%), stomach pain (11.5%), dehydration (3.8%), kidney pain (3.8%)
448 21.8 $\pm$ 1.8 years 49% M, 51% F	79% consumed EDs	Increased heart rate (36.9%), increased urination (26.2%), sleep deprivation (23.3%), increased weight (17.9%), headache (13.0%) and stress (9.8%)
98 24.9 $\pm$ 2.9 years 58% M, 42% F	49% consumed EDs	NR
1255 20.2 $\pm$ 1.9 years 45% M, 55% F	19.8% consumed EDs	Arrhythmias (26.1%), insomnia (23.3%), increased urination (21.7%), stomach pain (14.9%), nervousness (14.5%), nausea (12.9%), irritation and tension (10.8%), tiredness (9.2%), dehydration (7.6%), sight problems (3.6%), visit to the ER at the hospital (2.0%), seizures (0.4%), others (15.3%)
120 21.43 $\pm$ 1.77 years 100% M	43% consumed EDs; 37% used EDs daily	NR
412 21.43 $\pm$ 2.03 years 69% M, 31% F	45.6% consumed EDs; 32.5% consumed EDs as an irregular routine; consumers were mainly male ( $p<0.05$ )	Increased urination (14.9% M, 11.4% F), abnormal heart beat (9.0% M, 11.4% F), insomnia (4.8% M, 17.1% F), irritability (5.3% M, 5.7% F), stomach pain (4.8% M, 5.7% F), seizures (5.3% M, 1.4% F), crash after energy high (4.3% M, 8.6% F), decreases performance (4.3% M, 4.3% F), dehydration (3.7% M,

		2.9% F), problem with vision (4.3% M, 1.4% F), nervousness (3.7% M, 7.1% F), nausea (2.1% M, 5.7% F), emergency room visits (2.1% M, 0% F), headache (1.1% M, 0% F), kidney pain (0.5% M, 1.4% F), allergy (0.5% M, 0% F), abdominal pain (0.5% M, 0% F), muscle pain (0% M, 1.4% F)
1097 20-23 years 46% M, 54% F	65.6% ED consumers (52.6% low frequency, 13% high frequency); the high-frequency group was mainly composed by males ( $p < 0.001$ )	NR
2973 21.8 ± 2.9 (17 - 35) years 45% M, 55% F	27.2% consumed EDs; 19.6% used ED 1-5 times, 7.6 more than 5 times	NR
439 22.8 ± 2.09 (19 - 39) years 51% M, 49% F	48.3% consumed ED at least once; 33% were current users; 89.7% of these consumed <1 bottle/day	NR
2632 23.4 ± 2.3 (19 - 45) years 51% M, 49% F	59.9% consumed EDs within the last year; 26.4% consumed EDs within the previous 30 days; 73.9% of these consumed <6 days/month	NR
30 Age NR 83% M, 17% F	87.6% consumed EDs, 57% consumed 1-3 ED/week	NR
1257 ≤ 19 - ≥ 20 years 49% M, 51% F	68.9% consumed EDs; 53% tried ED once in lifetime and 15.7% consumed ED at least once a month	Palpitation (38.1%)
2001 21.1 ± 2.1 (17-36) years 43% M, 57% F	46.5% consumed EDs; 21.1% consumed occasionally EDs; consumers were mainly males ( $p < 0.001$ )	The most frequent side effects in those who used EDs at least once in life were palpitations (3.4%), sleeplessness (2.8%), headache (1.8%) and among those using EDs regularly sleeplessness (13.8%), thirst (10.3%), vertigo (6.9%)
508 20.4 ± 1.9 years 38% M, 62% F	21% consumed ED; 48.1% reported drinking one ED every 2-3 months, 22.1% 1 or 2 EDs/month	Accelerated pulse (36.2%), heart palpitations (31.4%), loss of appetite (15.2%).
794 21.9 ± 2.7 (19-41) years 47% M, 53% F	21.8% consumed EDs; 34% consumed EDs rarely	Palpitations (35%), insomnia (21%), irritability (20%), anxiety (16%), headache (13%), tremors (8%)
479 22.3 ± 4.4 years 36% M, 64% F	57% consumed EDs	NR
844 first-year undergraduates 42% M, 58% F	37.7% consumed EDs on at least one of the last 30 days	NR
606 23.0 ± 4.9 years 33% M, 67% F	51.8% consumed EDs, and 24.8% used ED in the previous 30 days; 82.7% used ED ≤1 time/week, 14% 2-3 times/week, 3.3% ≥4 times/week	NR
381 20-≥26 years 46% M, 54% F	11.5% consumed EDs; 8.7% consumed 1 ED/day consumers were mainly males ( $p > 0.05$ );	NR
1958 18.5 ± 0.6 years	16% consumed EDs; consumers were mainly males ( $p = 0.0121$ )	NR

39% M, 61% F		
100 18 - >23 years 61% M, 39% F	77% consumed EDs; 27% used ED 1–2 times/month, 20% 1–2 times/week	NR
467 21.9 ± 3.7 years 53% M, 47% F	40.1% consumed EDs; 35.3% consumed one to two cans daily	Increased urination (27.9%), headaches (25.3%), high heart rate (23.2%), insomnia (10.3%), diarrhea or constipation (7.9%), high blood pressure (1.9%), stomachache/nausea (3.0%), dehydration (6.2%), blurred vision (0.9%), trembling/irritability (1.7%)
919 17 – 25 years 26% M, 74% F	40.9% consumed EDs; consumers were mainly females (OR=2.5; 95% CI=1.9–3.5)	31.4% reported bad sleep quality
692 18-25 years 43% M, 57% F	36.4% consumed at least one ED in the previous 30 days; 17.6% consumed an 1–2 EDs; consumers were mainly males	NR
226 20.7 ± 0.1 years 47% M, 53% F	45% consumed EDs; 53.8% reported drinking at least one can per month (defined as regular consumption)	Increased heart beat (42%) shakiness (36%), dizziness (30%), anxiety/nervousness/irritability (29%)
265 18-≥22 years 32% M, 68% F	23.1% consumed EDs	Trouble sleeping (25%), shaking and tremors (20%), and stomachache (20%), headache (18%) heart palpitations (12%), tingling/ numbing skin (3%), chest pain (5%), dizziness (5%), addiction (5%), other (12%)
194 18 – ≥22 years 42% M, 58% F	28% consumed EDs	Shaking and/or tremors (35%), experienced stomachaches and/or gastrointestinal disorders (33%), trouble sleeping at night (25%)
400 22.2 ± 1.9 years 50% M, 50% F	53% consumed EDs	Anxiety (7.4%), thirst (6.0%), restlessness (5.4%), sleeplessness/insomnia (3.4%), irritability (2.7%), headache (2.0%), vertigo/dizziness (0.7%)
323 22.1 ± 1.8, 17 - 26 years 57% M, 43% F	63% consumed EDs; 43.7% consumed ED occasionally, 3.7% consumed ED regularly; consumers were mainly males (p<0.001)	Thirst (9.9%), headache (4.9%), irritability (4.5%), insomnia/sleeplessness (2.7%), anxiety (2.2%), restlessness (2.2%), and vertigo/dizziness (1.8%)
456 19-50 years (Median 24 years) 28% M, 72% F from University of Georgia (UGA) and Colorado State (CSU)	30% consumed EDs in the previous month; 43% UGA and 44% CSU are ED users, 45% CSU and 47% UGA are regular users.	NR
727 20.7 ± 1.9 years 37% M, 63% F	22.7% consumed EDs; 19.8% consumed 1-2 ED/day	NR
150 21.4 ± 1.7 years 22% M, 78% F	32.7% consumed ED; consumers were mainly males (66.7%; p<0.01)	55.11% of ED consumers had difficulty in sleeping: 32.65% have decrease duration, 34.69% have increased sleep latency, 18.36% have intermittent wakeups and 14.30% show multiple symptoms
1873 21.2 ± 2.4 years 39% M, 61% F	47.8% consumed EDs	NR
159	36% consumed EDs; 21.8% consumed ED 1-2 times	Sleep disturbances (later bedtimes, harder time falling asleep, and

19.9 ± 1.6 years 23% M, 77% F	in the last 30 days	more all-nighters), increased alertness (60%), increased heart rate (48%), enhanced academic performance (33%), and increased anxiety (27%)
1620 < 20-≥ 30 years 12% M, 88% F	78.1% consumed EDs; the mean number of cans per week was 1.63 ± 2.64; consumers were mainly female (p=0.001)	None (16.1%), palpitation (27.8%), sleep disorder (21.1%), gastrointestinal trouble (10.5%), headache (8.8%), elevation of blood pressure (4.5%), fatigue (3.0%), dizziness (2.8%), depression (2.4%), elevation of bodyweight (1.3%), feel thirsty (1.4%), other (0.2%)
2854 20.3 ± 1.3 years 32% M, 68% F	58% consumed at least one ED/month; consumers were mainly males (p<0.001)	NR
1246 19.9 ± 1.7 years 35.8% M, 63.7% F, 0.1% transgender, 0.4% other	32% consumed EDs in the past 30 days, 18% in the past-week	NR
830 24.7 ± 7.2 years 42% M, 58% F	87.8% consumed EDs; 33% consumed ED in last 30 days, 2.1% reported daily use	NR
1248 16 - ≥ 23 36% M, 64% F	36.4% consumed EDs; consumers were mainly males (p=0.018) and older (p=0.001)	NR
1248 16 - ≥ 23 years 35.8% M, 64.2% F	36.4% consumed EDs	NR
899 18 - ≥ 28 years 31% M, 69% F	38.6% consumed EDs; consumers were mainly males (p<0.05) and younger (p<0.05)	NR
496 21.5 ± 3.7 years 38% M, 62% F	51% consumed more than one ED/month; consumers were mainly female (p=0.01)	Weekly jolt and crash episodes (29%) headache (22%), heart palpitations (19%)
449 23 ± 5.2 years 33% M, 67% F	41.2% consumed EDs	Jolt and crash episodes (53.5%) and/or heart palpitations (43.8%)
104 42.3% M 57.7% F	78.8% consumed EDs; 5.8% consumed ED daily, 8.7% 3-5 times/week, 8.7% 1-2 times/week, 10.6% 2-4 times/month, and 45.2% less than once/month	Weight gain (10.6%), palpitations or tachycardia (31.7%) insomnia (50%), neuropsychosis (2.9%)
795 52% M, 48% F	39% consumed at least 1 ED in the past 30 days; consumers were mainly male (p<0.01)	NR
602 19.98 ± NR years 52% M, 48% F	>1/3 consumed at least 1 ED/last month: 538 low consumption (≤1-2/week), 60 high consumption (>1-2/week); consumers were mainly male (p<0.01)	NR
548 19.9 ± 2.1 years 59% M, 41% F	51.5% consumed EDs	Increased urination (16.6%), heart palpitations (11.9%), insomnia (10.1%), headache (7.0%)

a	157 18 - > 24 years 60% M, 40% F	27.7% consumed EDs; 79.1% consumed 1-4 energy drinks in an average month; consumers were mainly males (p=0.006)	Poor sleep quality
	500 22.0 ± 2.3 (18-36) years 47% M, 53% F	35% consumed supplements, and 41% of these were EDs	Insomnia (23%), excessive stimulation (20%), muscle trembling (15%), gastrointestinal problems (13%), addiction (5%), increase in blood pressure (5%)
	116 18 - >25 years 49% M, 51% F	51.8% consumed EDs; ED cans consumed per week: 8 oz (74%); 12 oz (11%); 16 (6%); 20+ oz (9%)	Higher stress levels
	692 20.4 ± 1.4 (18-25) years 43% M, 57% F	36.4% consumed EDs (at least 1 ED/last month); consumers were mainly males (p<0.001)	NR
	136 18-24 years 39% M, 61% F	29.1% consumed at least 1 ED in the previous day, 59.1% in the previous 7 days, and 70.1% in the previous 30 days	NR
	10,283 ≤17 - ≥25 years 33% M, 67% F	9.1% consumed EDs	NR
	585 19 ± NR years 44% M, 56% F	56.4% consumed EDs; 77.3% consumed EDs 1-3 times/week	NR
	337 100% F	81.3% consumed EDs regularly; 42.4% consumed 1 ED/day	Headache (32.3%), stomach pain (21.0%), increased urination (11.2%), restlessness (9.7%), increase blood pressure (9.2%), tingling (7.1%), nervousness (6.0%), menstrual disturbances (4.3%), abdominal pain (3.0%), allergy (2.0%)
b	1994 19 - ≥ 40 years 34% M, 66% F	86% consumed EDs; 38% were current users	NR
	1994 19-≥40 years 34% M, 66% F	86.2% consumed EDs; 38% were current users; 74% consumed five or less drinks in an average month	None (35.7%), restlessness (22%), jolt and crash (17.1%), elevated heart/pulse rate (16.6%), anxiety (13.3%), increased urination (11.6%), insomnia (11.2%), twitch or tremor (8.5%), headache (7.8%), irritability (7.8%), other (1.8%)
	614 19.6 ± 1.4 (18-25 years) 22% M, 78% F	15.6% consumed at least 1 ED in the previous week	NR
	275 21-53 32% M, 68% F	29% consumed EDs; consumers were mainly males (p<0.05)	NR
	426 18 - 24 years 65% M, 35% F	90.61 consumed EDs; 28.8% consumed ED once per week	Increased blood pressure (9.3%), increased heart rate (12.4%), sleeplessness (9.6%), headache (5.2%), nervousness (8.0%), fatigue (10.0%), nausea (5.0%), vomiting (5.0%), diarrhoea (54.4%), no any (3.6%)
	298 23.03 ± 6.53 (18-52) years 37% M, 63% F	39.2% consumed EDs at least once/week; the number of ED/week ranged from 0 to 15+	NR

812 21.4 ± 2.0 years 27% M, 73% F	61.2% consumed EDs; 43.2% consumed EDs rarely	NR
407 ≤ 18 years - ≥ 24 years 55% M, 22% F	52.1% consumed EDs. 35.87% consumed ED ≤2 times/week, 16.22% ≥3 times/week	NR
8516 22.2 ± 2.0 (18- 30) years 33% M, 67% F	38.7% consumed EDs; 21.0% consumed ED once/week; heavy consumers were mainly female (p<0.05)	NR
486 20.38 ± 4.1 years 38.5% M, 60.3% F	Mean ED use was 2.52 (SD = 1.53), as defined by the CORE survey response scale. As such, mean ED use among the sample was 2-5 days in the past 30 days	NR
260 21.9-24.0 years 45% M, 55% F	10.8% consumed EDs	NR
585 18.7 ± NR years 44% M, 56% F	40% consumed ED in the past month and 17.5% consumed ED in the past week; consumers were mainly males (p<0.0001) and white (p=0.05)	NR
1007 22.7 ± 4.41 years 39% M, 61% F	75.8% consumed EDs	NR
605 21.96 ± 4.22 years 33% M, 67% F	48.9% consumed EDs in the previous 30 days	NR
267 22.95 years 36% M, 64% F	83% consumed EDs within the past year	NR

NR = Not Reported

**Table 2.** Health-related behaviors and motivation associated with Energy Drinks (EDs) consumption in the selected studies

Author, Year [Ref]	Associated health-related behaviors	Reason
Abukhelaif et al., 2020 [33]	NR	To enhance academic performance alertness and attention and for driving activity (13%)
Alafif et al., 2021 [34]	ED consumption was associated with the consumption of less than three meals per day ( $p = 0.002$ ), skipping breakfast ( $p=0.028$ ) and with fast-food intake ( $p=0.010$ )	Nice taste (53.6%)
Alqassim et al., 2021 [35]	ED consumption was more common in smokers ( $p=0.009$ )	To enjoy the taste (78.3%), to stay awake (20.8%), to increase study concentration, to relieve depression, or to relieve headaches
Al Sawah et al., 2015 [36]	NR	For studying, for wakefulness, to improve performance
Alabbad et al., 2019 [37]	NR	To keep friends' company (26.1%), to stay awake (61.4%), to improve alertness, to increase physical activity (53%)
Aljaloud, 2018 [38]	NR	Energy boost (51%), recovery from fatigue, tolerance for additional training (12%), to improve endurance (12%), with pain and improve endurance (12%)
Alsunni and Badar, 2011 [39]	NR	To give company to friends, to keep energy (males and females), for betting in sports (males), for better performance, to enjoy taste (males and females)
Arria et al., 2011 [40]	High-frequency ED consumption was associated with alcohol use, alcohol dependence and alcohol abuse ( $p<0.05$ )	NR
Atlam et al., 2017 [41]	Use of EDs increase the risk of experience substances including tranquilizing medication, hallucinogens, ecstasy, heroin, cocaine, narcotic drugs, and volatile substances ( $p<0.001$ )	NR
Attila and Cakir, 2011 [20]	ED consumption was associated with alcohol drinking ( $p<0.001$ )	24.4% consumed ED to feel "more energetic"
Bahadirli et al., 2018 [42]	NR	NR
Bliss and Depperschmidt, 2011 [43]	NR	Needing more energy (23%), driving, studying for an exam/completing homework
Borlu et al., 2019 [44]	ED consumption was associated with smoking (OR=1.52; 95% CI=1.02–2.26), alcohol use (OR=3.22; 95% CI=2.18–4.77), and regular physical activity (OR=2.29; 95% CI=1.21–4.26)	To stay awake (15.8%) to be strong
Bulut et al., 2014 [45]	ED consumption was positively associated with physical activity and alcohol use ( $p<0.001$ )	For curiosity (51.3%), to enhance performance, to overcome sleepiness (9.2%), to increase energy (9.2%), to feel less sleepy (20.7%), to study, to increase circle of friends (13.8%), to decrease stress (13.8%)
Cabezas-Bou et al., 2016 [46]	ED consumption was associated with playing sport in official university teams ( $p=0.002$ )	To study (72.1%), during social activities (18.3%), during sexual activities (9.6%)
Casuccio et al., 2015 [47]	ED consumption was associated with alcohol ( $p=0.34$ ) and caffeine ( $p<0.005$ ) consumption	NR
Cecilia et al., 2016 [48]	ED consumption was associated with regular smoking ( $p=0.02$ )	To stay awake, to treat a hangover, to increase energy
Champlin et al., 2016 [49]	NR	NR



[49]		
Chang et al., 2017 [50]	Using tobacco (OR=2.0, 95% CI=1.3–2.9) or alcohol (OR=2.1, 95% CI=1.1–4.1) significantly predicted ED consumption	To keep alert at work (48.7%), to be able to enjoy the flavor (31.3%), to prepare
Choi, 2020 [51]	NR	Desire of alertness and health benefits
Dillon et al., 2019 [52]	ED consumption was associated with alcohol use (p<0.0001) and intake (p<0.0001), problem alcohol behaviors (from OR=1.87, 95% CI:1.20–2.92 to OR= 2.43, 95% CI:1.83–3.24), nonmedical drug use (from OR=2.36, 95% CI:1.85–3.00 to OR=3.52, 95% CI:2.01–6.16)	NR
Dwaidy et al., 2018 [53]	NR	To enjoy the taste (29%), to help to get energy (13%), to help feel better (21%)
Elsahoury et al., 2021 [54]	ED consumption was more common in smokers (p<0.001)	No reason/tasty (36.8%), to stay awake and for energy boost (47.4%) or mental focus (7.9%), to treat headache after to recover the injury or illness (1.1%),
Faris et al., 2017 [55]	ED consumption was negatively associated with smoking (OR=0.15; 95% CI=0.1–0.2) and eating breakfast (OR=0.61; 95% CI 0.38–1.0) and positively associated with physical activity (OR=1.1; 95% CI=0.8–1.4)	The highest rates of ED consumption were among highly stressed and in the case of first submission
Gallucci and Martin, 2015 [56]	Higher ED consumption was more common in non-athletes (p<0.05); ED consumption was associated with current tobacco use (p<0.01) and frequent heavy episodic drinking (p<0.001)	Student non-athletes: lack of sleep (66.0%). Student athletes: need for mental focus (50.0%)
Ghozayel et al., 2020 [57]	ED consumption associated with being physically active (p=0.001) and consuming other beverages, including alcohol (p=0.032), coffee (p=0.005) and sports drinks (p<0.001)	To get energy to study (47%) or to stay awake/prevent sleep (20%)
Hardy et al., 2021 [58]	NR	To feel more alert (64%), to enjoy to work or to study (45%)
Hardy et al., 2017 [59]	NR	To enjoy the taste (54%), to enhance
Hasan et al., 2020a [60]	ED consumption was associated with smoking (p=0.003) and regular physical activity (p=0.010)	To increase concentration while studying during exercise (1.9%), to feel energetic for a particular reason (37.5%)
Hasan et al., 2020b [61]	ED consumption were associated to doing regular physical activity (OR=1.69; 95% CI=1.04-2.75)	To feel taste (57.4%), recommend availability (11.2%), media advertisement (5.8%), appeal of the drink (4.0%)
Hofmeister et al., 2010 [62]	35% were over the counter stimulant and depressant medicines users; EDs use was associated with high consumption of caffeine in 31% and 37% of the two university groups	The most common reasons were to help study, remain awake, or wake up in the morning
Jahrami et al., 2020 [63]	NR	NR
Javed et al., 2017 [64]	NR	NR
Johnson et al., 2016 [65]	NR	To keep me awake (61.9%), to enjoy (47.1%)
Kelly and Prichard, 2016 [66]	Consumption of at least 3 EDs in the last month was associated with not wearing bike helmet and using alcohol (p<0.1), not wearing seat belt and using cigarettes, marijuana, hookah, and illicit prescription drugs (p<0.01)	Long drive (69%), hangover (67%), sleep (63%), studying (61%), more long work shift (50%), enhanced at
Kim and Kim, 2015 [67]	NR	The most frequent reason for using
Lohsoonthorn et al., 2013 [68]	NR	NR
Luneke et al., 2020	NR	To wake up (57.4%), to aid in studying

[69]		(34.3%), to concentrate (19.6%), to reduce thirsty (18.1%), to party (12 longer (7.3%), out of habit (5.2%),
Maidana et al., 2020 [70]	NR	NR
Mahoney et al., 2019a [17]	ED consumption more common in students using tobacco ( $p<0.001$ ) and exercising with team ( $p=0.020$ )	To feel more awake (79%), enjoy tl friends or family (39%), improve co energy (27%), improve mood (18%)
Mahoney et al., 2019b [71]	Former and current smokers were mainly represented among ED consumers ( $p<0.001$ )	NR
Majori et al., 2018 [72]	NR	Academic reason (22.7%), one othe
Malinauskas et al., 2007 [21]	NR	To increase energy (65%), to drink or complete a major course project
McGaughey et al., 2018 [73]	NR	Lack of sleep, for more energy, and
Mehwisharif et al., 2019 [74]	NR	No special occasion (26.9%), durin (28.8%), during exams (25.0%), du
Miller, 2008a [75]	Higher frequency of ED consumption was positively associated with marijuana use, sexual risk-taking, fighting, seatbelt omission, and taking risks on a dare ( $p<0.01$ )	NR
Miller, 2008b [76]	Higher frequency of ED consumption was positively associated with marijuana use, fighting, taking risks on a dare ( $p<0.001$ ), seatbelt omission and sexual risk-taking ( $p<0.05$ ) for the sample as a whole, and associated with smoking, drinking, alcohol problems, and illicit prescription drug use for white students ( $p<0.001$ )	NR
Murad and Rafeeq, 2016 [77]	NR	Enjoyment, long driving, studying, thirst
Mwape and Mulenga, 2019 [78]	NR	To increase concentration while stu (67.4%), completing a course proje
Nessler et al., 2020 [79]	NR	To reduce the feeling of being tired (61%), to increase concentration pr an examination (20%)
Newlon and Lovell, 2016 [80]	NR	Psychological reasons and mental h
Oglesby et al., 2018 [81]	NR	To have more energy (61.8%), to st better while studying (38.2%), to in concentrate better in class (23.1%),
Pettit et al., 2011 [82]	NR	To prepare for stressful events such major projects
Picard-Masson et al., 2017 [83]	Weekly ED consumption was associated with consumption of $\geq 20$ cups of coffee/week OR=2.43; 95%IC=1.66–3.56 or OR=1.63; 95%IC=1.08–2.45, smoking OR=3.99; 95%IC=3.42–4.64 or OR=2.62; 95%IC=2.21–3.10, excessive use of alcohol OR=2.24; 95%IC=1.95–2.58 or OR=1.60; 95%IC=1.38–1.86, past use of cannabis OR=2.46;95%IC=2.15–2.82 or OR=1.41; 95%IC=1.20–1.66, glues or solvents OR=9.74; 95%IC=4.21–22.52 or OR=4.20;95%IC=1.40–12.65 or amphetamines OR=4.00;95%IC=3.33–4.80 or OR=2.23; 95%IC=1.76–2.84	NR
Poulos and Pasch, 2015 [84]	Eds users had a significantly greater BMI ( $p<0.05$ ) and consumed more soda ( $p<0.01$ ) and frozen meals ( $p<0.05$ )	NR
Rahamathulla, 2017 [85]	NR	To give company to friends (59.4% better performance in exams (41.29 (39.4%))

Reid and Gentius, 2018 [86]	ED and alcohol consumption was reported by 27%, with males more likely to use alcohol and energy drinks together than females ( $p < 0.05$ )	Energy boost (26%), staying awake (21%), sports (12%), mixing with a treating hangovers (1%)
Reid et al., 2015 [87]	NR	To seek a boost in energy (50%), to major project (40%), to control weight a hangover (10%), to play sports (2)
Reuter and Forster, 2021 [88]	NR	NR
Rios et al., 2013 [89]	NR	The main reason for consuming ED of time (54.0%)
Shaikh et al., 2018 [90]	NR	Good taste (62%), to increase work waking hours (10.4%), to increase 1
Skewes et al., 2013 [91]	ED consumption was significantly associated with hazardous drinking ( $p < 0.001$ )	NR
Sljivo et al., 2020 [92]	Drinking coffee predicted EDs consumption ( $p < 0.001$ )	To stay awake (58.2%), good taste or concentration for studying (35.7% to cure hangovers (2.4%), to improve stimulate metabolism (5.0%)
Spierer et al., 2014 [93]	ED consumption was related with drinking alcohol to inebriation and driving ( $p < 0.05$ ) and riding with a drunk driver ( $p < 0.05$ )	NR
Teleman et al., 2015 [94]	NR	NR
Trunzo et al., 2014 [95]	NR	NR
Uzundumlu et al., 2016 [96]	ED consumption was associated with cigarette smoking ( $p < 0.001$ ), using Internet ( $p < 0.01$ ) and not having breakfast ( $p < 0.05$ )	NR
Velazquez et al., 2012 [97]	greater ED consumption was associated with a higher alcohol consumption ( $p < 0.001$ )	NR
Vitiello et al., 2016 [98]	Habitual ED consumption was associated with not having breakfast and a varied diet, consuming sweets at the end of the meal, sport drinks, wine, beer, drink or alcoholic drink ( $p < 0.05$ )	energizing effect (32.5%), enhance used ED when studying very hard, evenings to maintain high activity 1
Woolsey et al., 2014 [16]	NR	NR
Woolsey et al., 2015 [99]	ED consumption was associated with having reported a stimulant prescription ( $p < 0.0001$ )	NR

NR = Not Reported

The included articles were published between 2007 and 2021 and were performed in several countries: 27 of them were conducted in the USA, [16, 17, 21, 36, 40, 42, 49, 52, 55, 58, 59, 60, 64, 69, 71, 73, 75, 76, 80, 82, 84, 88, 93, 95, 97, 99], 8 in Saudi Arabia, [33-35, 37-39, 77, 85], 6 in Turkey, [20, 41, 42, 44, 45, 96], 5 in Italy [47, 48, 72, 94, 98] and 3 in Pakistan [64, 74, 90]. Other countries are less represented: 2 of them were performed in the Bahrain [55, 63], Bangladesh [60, 61], Korea [51, 67], Lebanon [53, 57], Puerto Rico [46, 89], United Kingdom [59, 65], and only a study was conducted, respectively, in Bosnia Herzegovina

[92], Brazil [70], Canada [83], Caribbean [87], Jordan [54], Poland [79], Taiwan [50], Thailand [68], Trinidad and Tobago [85], and Zambia [78]. The bibliographic and scientometric data for all articles were reported in Table S2. 25 of 71 papers were published on journals which do not have the Journal Impact Factor (JIF) [35,37-39,41,43,45,52-54,60,61,64,67,70,72-74,78,79,87,90,92,95] 18 journals have JIF between 0.219 and 1.883 while 27 have JIF between 2.333 and 7.325 and only one has a JIF above the threshold of 20 [40].

All the studies included male and female subjects with a range of 16-53 years; most of them involved a large sample size (from 30 to 10.283) and a high variety in ethnicity.

The evaluation of ED consumption frequency is based on a weekly report for most of the studies [34, 36, 39, 43, 50, 58, 67, 71, 74, 80, 84, 88, 90, 91, 93, 94, 96] or divided into daily, weekly, monthly and rarely consumption, or else [38, 45, 47, 53, 70, 82, 83, 92] Some of them reported the proportion of occasional and regular users [20, 45, 57, 61, 85] or describe the number of ED cans in a specific period. [20, 35, 54, 57, 67, 74, 80, 90]. As for the prevalence of ED users, it ranges from 9% reported in the study by Picard-Masson et al. [83] to 90.6% in the study by Shaikh et al. [90] With regards to the geographic areas, prevalence values ranged from 11.5 to 90.6% [51, 90] in Asian countries, from 9.1 to 87.6% [83, 43] in North America, from 10.8 to 75.8% [96, 98] in Europe. Only South America showed a prevalence of ED use always higher than 86%, although it was analyzed by only three studies [70, 86, 87]. However, only five studies reported a prevalence lower than 20% [37, 51, 52, 88, 96]. A total of 21 articles analyzed the ED consumption by gender: 18 of these reported higher prevalence or higher frequency of use among males [17, 33, 39, 40, 45, 51, 52, 55, 61, 64, 68, 72, 75, 76, 78, 81, 89, 97]. Adverse effects related to ED consumption were investigated in 30 out of the selected articles. Disturbances in sleep [33-35, 37, 39, 45, 47, 54, 55, 58, 59, 61, 64, 66, 67, 74, 77-79, 85, 87, 89, 90] and heart functions disorders [21, 33-35, 37, 39, 44, 45-47, 54, 57, 58, 65, 67, 73, 74, 77, 81, 85, 87, 89] were mainly reported by participants (24 and 22 studies respectively).

A total of 35 studies analyzed health-related behaviors associated with ED consumption. The most commonly reported behaviors were alcohol use or abuse (16 studies) [20, 40, 44, 45, 47, 52, 55, 57, 65, 75, 76, 84, 86, 91, 93, 97, 98] smoke tobacco (11 studies, 10 of which showing positive association) [44, 48, 49, 55, 56, 61, 66, 71, 75, 76, 83, 96] and physical activity/sport (10 studies, 9 of which showing positive association). [17, 44-47, 55, 57, 61, 71] Forty-eight studies investigated the reason why EDs were used. The majority of them (37 studies) reported reasons related to study and examinations [17, 21, 33, 35-37, 39, 41,

43-47, 50, 53, 55-59, 61, 62, 65, 69, 72-74, 77-79, 81, 82, 85-87, 90, 91, 98], while in 21 studies users declared ED consumption to keep themselves awake or alert [17, 33, 35, 39, 45, 48, 50, 54, 56-58, 62, 65, 67, 69, 79, 85-87, 89, 92] and in 18 studies reasons related to physical activity/sport performance were reported [17, 33, 35, 37, 39, 45, 46, 48, 53, 56, 57, 71, 66, 69, 74, 86, 87, 91].

The estimated overall prevalence of ED consumption (Figure 2) was 42.9% in undergraduate students (95% CI:42.5%-43.3%), with significant heterogeneity among studies (Q test:  $p < 0.001$ ;  $I^2 = 99.4\%$ ). Sensitive analysis did not substantially change the pooled prevalence of ED consumption, which resulted equal to 45.2% (95% CI: 46.9%-43.5%) after the exclusion of Abukhelaif et al. [33], suggesting that no one single study had a disproportional impact on overall prevalence.

Journal Pre-proof

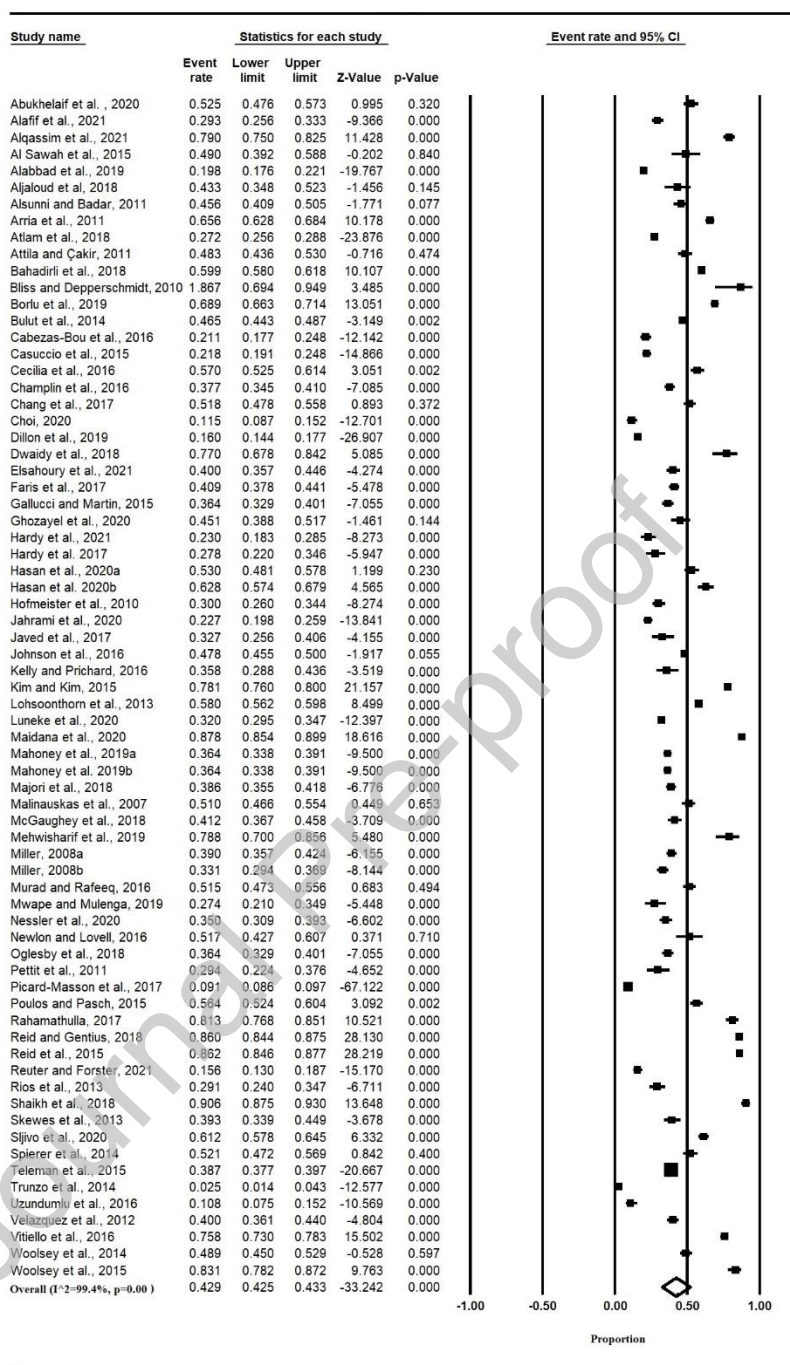


Figure 2. Forest plot for the prevalence of ED consumption in students.

Visual inspection of funnel plot suggested the lack of publication biases in the present study ( $p=0.120$ )

(Figure S1).

To investigate the effects of potential factors influencing the heterogeneity of the global prevalence of ED consumption, a meta-regression analysis was performed considering gender, age, sample size, publication year, methodological quality of the study and WHO region in which the study was conducted. Meta-regression showed that the prevalence of ED consumption was independent by the percentage of women ( $p = 0.852$ ), mean age ( $p = 0.135$ ), or methodological quality ( $p = 0.865$ ). Moreover, the prevalence of ED consumption decreased with the increase of sample size ( $p < 0.05$ ) (Figure 3).

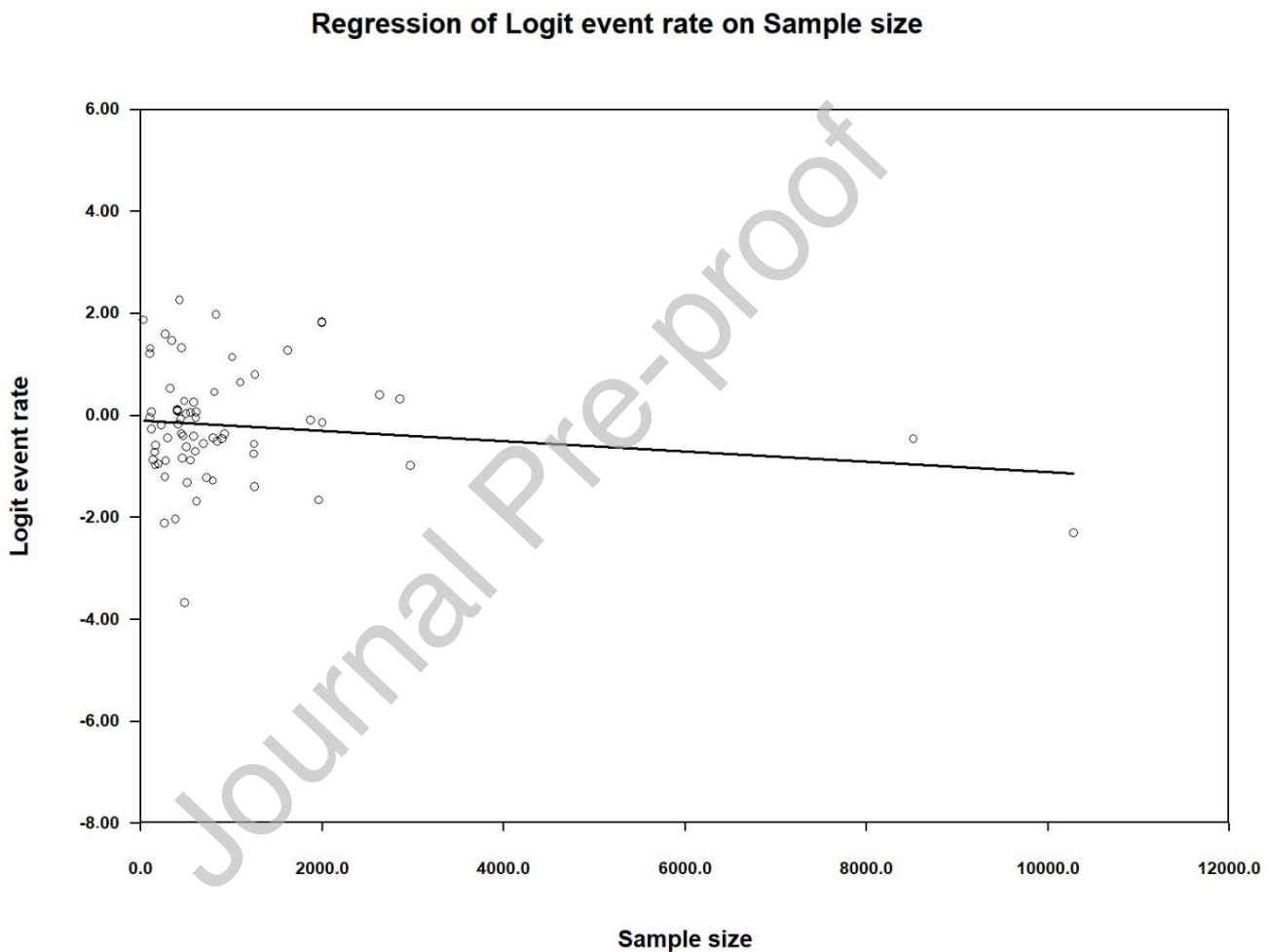


Figure 3. Meta-regression chart of the prevalence of ED consumption in the world by sample size

In addition, the prevalence of ED consumption in the world slightly showed a decrease with the increase of the year in which the study was conducted ( $p < 0.05$ ). The study location was a significant moderator according to the subgroup analysis ( $Q=13.57$ ,  $df=7$ ,  $p < 0.05$ ). The subgroup analysis among the WHO

regions showed that the prevalence of ED consumption was 28% in AFR Region, 42% in AMR Region, 49% in EMR, 50% in EUR, 62% in SEAR.

#### 4. DISCUSSION

According to the surveys performed in different countries, young adults represent one of the population groups most interested in ED consumption and that which showed the highest increase in the prevalence of ED use across the last decades [100-104]. Within this age group, university students seem to be particularly keen to use EDs in order to deal with their study or sport related needs [48]. This review was aimed at analyzing the existing literature on ED use among university students in order to highlight the most common patterns of consumption in this target population. Notwithstanding a great variability found regarding the prevalence of ED consumers in the populations studied, some common features regarding ED use emerged.

A wide range of ED users was found across the selected studies. The prevalence of ED consumption ranged widely (about 10-90%) in quite all the investigated geographic areas, suggesting that sociocultural factors related to residence may not influence the use of EDs in this population group. The differences in estimated prevalence of ED consumption were associated with sample size and study location, and independent by gender, age and methodological quality. The study location was a significant moderator and EUR and SEAR WHO region showed the major prevalence of ED consumption. With regards to this, it should be noted that some ED manufacturing company is placed in European and Saudi Arabia countries and in Arabian Emirates, and in general students tend to drink local brands, which are less expensive. [76]

The 93% of the articles reported ED use in more than a fifth of the samples, confirming that undergraduates in world are consistently interested in this phenomenon. With regard to this, it should be noted that students are not always aware of the possible health effects of EDs and many of them consider these products safe. [38,54] Furthermore, in the study by Hardy et al., ED users showed also lower knowledge on human nutrition, especially regarding sources of foods/nutrients and diet–disease relationship, assessed through the General Nutrition Knowledge Questionnaire for adults (GNKQ). [58, 105]

In line with the EFSA opinion, moderate consumption of EDs, corresponding to single caffeine intake of up to 200 mg, does not result in clinically relevant cardiovascular changes in young healthy adults. [105, 107] However, high intake of EDs is associated with moderate and severe adverse effects. Moreover, EDs and



energy shots exceed and sometime double or triple the soft drink caffeine concentration limit that is considered as safe, leading to negative effects such as reduced vasodilatation and myocardial perfusion, which may determine increase in heart rate and blood pressure. [108] In addition, the prolonged assumption of the other ingredients which contribute to the stimulatory effects of EDs such as taurine, sugar and B-vitamins may affect the cardiovascular system, raising the overall risk for short and long-term outcomes. Indeed, arrhythmias, myocardial infarctions, cardiomyopathies, and sudden cardiac death have been linked to EDs consumption. [109]

As for the reason that leads students to ED use, it seems that engagement in study, projects or examinations play an important role. However, it should be considered that in their study Oglesby et al. did not find significant differences in study hours between those ED users that declared academic reasons as motivations for using an ED and those who reported other reasons, which testify a lack of expected outcomes. [81] Furthermore, many undergraduates assume EDs to stay awake or alert. This is worth of interest considering that one of the main adverse effects reported by students was sleep disturbance. Moreover, problems related to cardiovascular system such as increased heart rate or blood pressure were highly reported. Another of the main reasons for ED use was identified in PA/sport engagement. This data agrees with the association between PA/sport and ED use found in nine studies. Although evidence about the positive association between ED use and athletic performance in some sports has been shown, [110] several studies reported an increasing risk of negative outcomes for cardiovascular system and a worsening of pre-existing mental conditions or addiction, especially in high-risk groups such as those genetically predisposed to these disorders. [111]

Among the other health-related behaviors associated with ED consumption, alcohol and smoking were the most commonly reported. Considering the possible consequences of these behaviors on health, this aspect is worrying and highlights the need of implementing educational interventions focused on the use and abuse of these substance in populations mainly interested. In particular, although this review was not aimed at assessing the use of alcohol mixed with EDs (AmEDs), literature shows that this habit is very common among ED users and can increase the risk of several injuries. [112] For example, Nadeem et al., in their systematic review and meta-analysis on adverse effects related to ED consumption, showed that mixing alcohol with EDs significantly reduced the likelihood of sedation effects and increased the probability of stimulatory effects. [113] Therefore, the authors recommended to avoid frequent ED consumption (5-7

energy drinks/week) and co-consumption with alcohol, and to adopt regulatory standards in the sale of EDs, particularly with regard to the pediatric population. Further research is needed to strengthen this evidence in a regulatory perspective.

The present review has some limitation. First of all, the characteristics of the populations examined in the selected studies were very different in sample size, age of participants, origin and gender composition, and even in educational areas. Furthermore, the measures used for assessing prevalence of ED use widely differed throughout the studies. Therefore, it was not possible to compare their results referring to standard quantities of EDs or to perform a meta-analysis. Moreover, the other variables investigated were not assessed in all the studies. Finally, the literature search did not include articles written in other languages than English. Therefore, it is possible that our analysis missed a piece of the available literature on this issue. However, to our knowledge this is the first tentative to systematically assess patterns of ED consumption in university students. The width of our eligibility criteria allowed us to observe this behavior in a great number of students worldwide. Although not applicable to all the undergraduates' populations, our findings suggest that ED abuse and related behaviors should be further investigated to detect and counteract their possible predictors.

In the future, the definition of standard measures for ED use could allow to better characterize the epidemiology of ED consumption at a global level, exploring its association with sociodemographic and behavioral factors. Moreover, the adoption of suitable criteria for the early identification of high-risk users can also represent a fundamental future direction of the research on this field.

## **5. CONCLUSIONS**

University students, especially males, commonly use EDs in order to achieve better academic or physical performance. However, this consumption may have negative health consequences, especially on sleep and cardiovascular or nervous systems. Furthermore, the association between ED use and unhealthy behaviors such as alcohol use and smoke pose important threats for public health. Identifying possible groups at risk for these behavioral patterns may be useful to address educational interventions aimed at preventing related health consequences.

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