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2 **Energy drink consumption is associated with anxiety in and mental health problems**
3 **~~among~~ Australian young adult males**
4

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22

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26 caffeine; Raine Study

27 **Abstract:**

28 **Background:** Energy drinks are predominantly targeted to young adult consumers however
29 there has been limited research into their effects on psychological functioning in this
30 demographic group. This study examined cross-sectional associations between energy drink
31 consumption and mental health in a population-based sample of young adults participating in
32 the Western Australian Pregnancy Cohort (Raine) Study.

33 **Methods:** We used self-report questionnaires to assess energy drink consumption and mental
34 health (Depression Anxiety Stress Scale-21; DASS-21) at the 20 year cohort follow-up. In the
35 ~~cross-sectional~~ regression analyses, we considered associations between energy drink
36 consumption (~~frequency and~~ mL/day) and continuous DASS-21 scores, adjusting for socio-
37 demographic variables, alcohol and drug use, physical activity, body mass index (BMI) and
38 dietary intake. Our sample included 502 males and 567 females (mean age 20±3 years).

39 **Results:** After adjusting for potential confounding factors and controlling for co-existing
40 mental health problems, energy drink consumption (per 100mL/day) was significantly
41 associated with ~~higher depression ($\beta = 0.682$; 95% CI = 0.108, 1.255)~~, anxiety (but not
42 depression or stress), and this relationship was found only in males ($\beta = 0.68632$; 95% CI =
43 0.05334, 01.58039), stress ($\beta = 1.026$; 95% CI = 0.458, 1.593) and total DASS-21 scores ($\beta =$
44 2.394; 95% CI = 1.084, 3.704) in males only. Among males, DASS-21 scores increased as
45 frequency of energy drink consumption increased (test for trend $p < 0.05$).

46 **Conclusions:** Our study found that energy drink consumption (~~both frequency and amount~~)
47 was associated with increased ~~depressive~~, anxiety ~~and stress symptoms~~ in young adult males.
48 Further research into the possible contribution of energy drink use to the development of
49 mental health problems in young adults is needed.

50

51

52 Introduction:

53 Energy drinks are now available in over 140 countries and represent the fastest growing
54 beverage segment, with global sales in excess of \$30 billion.^[1,2] Consumption of these highly
55 caffeinated beverages is most common among adolescents and young adults,^[3] with past
56 month prevalence estimates ranging from 34% to 57%.^[4-7] Energy drink consumption has
57 been shown to be positively associated with high-risk behaviour, including alcohol abuse,
58 illicit drug use, cigarette smoking, aggression and risky sexual behaviour.^[5,6,8] Emerging
59 evidence also suggests that energy drinks may exacerbate or contribute to anxiety,^[9] acute
60 mania,^[10] seizures,^[11] and mood and behaviour problems.^[12-14] Concerns over the side effects
61 of excessive energy drink consumption have resulted in some countries imposing mandatory
62 labelling of caffeine content, capping the amount of caffeine energy drinks can contain,
63 restricting sales or banning energy drinks altogether.^[2,15] Despite these concerns, a recent
64 systematic review investigating the psychological effects of energy drinks reported a paucity
65 of studies on public health implications of energy drink use and called for more research in
66 this area.^[13] There is emerging evidence that high levels of soft drink consumption are
67 associated with mental health problems in adolescents, with the emotional symptoms
68 implicated including mental distress, hyperactivity, conduct problems and suicidal
69 behaviours.^[16,17] A similar relationship may exist in adults, with one South Australian study
70 also reporting a positive association between consumption of soft drinks and mental health
71 problems.^[18] In this study, those who consumed more than half a litre of soft drink per day
72 had approximately 60% greater risk of having depression, stress-related problems, suicidal
73 ideation, psychological distress or a current mental health condition, compared with those not
74 consuming soft drinks. Whilst the mechanisms of these relationships are not clear,
75 constituents of soft drinks, such as refined sugars, caffeine, preservatives, flavouring and
76 colouring agents may have a causative role to play.^[19] Indeed caffeine, a major constituent of

77 soft drinks and energy drinks has previously been implicated in the causation of mental
78 disturbances. For example, moderate caffeine intake (< 6 cups/day) has been associated with
79 lower depressive symptoms, fewer cognitive failures, and lower risk of suicide whilst high
80 doses of caffeine can induce psychotic and manic symptoms, and more commonly, anxiety
81 (see Lara et al^[20] for a review).

82
83 To date investigations into energy drinks and mental health are relatively limited. In
84 patient case studies, symptoms of severe anxiety have been reported with chronic heavy
85 consumption (six to eight servings daily) of an energy drink, with symptoms subsiding after
86 cessation of use.^[9,21] There have also been reports of psychosis temporally associated with
87 energy drink consumption in individuals with an existing mental health disorder^[22,23] and in a
88 patient with no history of psychiatric illness.^[10] Furthermore, teachers have reported more
89 behavioural issues with students who admit that they are drinking energy drinks.^[14] In two
90 US college samples, consumption of energy drinks has been associated with anxiety^[24] and
91 anxiety related symptoms^[4] such as heart palpitations, headaches and “jolt and crash”
92 experiences, with significant dose effects related to these findings. Thus, more research into
93 the effects of energy drink use on psychological variables appears warranted Little is known
94 as to whether there is a direct relationship between energy drink consumption and mental
95 health problems among young adults and there are no population studies that have been done
96 in this field to date.

97
98 The purpose of this study was to investigate the association between energy drink
99 consumption and mental health problems in a population-based sample of young adults
100 participating in the Western Australian Pregnancy Cohort (Raine) Study.

101

102 Methods:**103 Participants**

104 Participants were drawn from the Western Australian Pregnancy Cohort (Raine) Study, a
105 prospective cohort study that has followed participants from gestation to early adulthood.
106 Detailed methods regarding the Raine Study have been published previously.^[25] Briefly,
107 2,900 pregnant women at 16 to 20 weeks gestation were recruited between 1989 and 1991
108 through the public antenatal clinic and local private clinics in Perth, Western Australia. Of
109 these, 2,804 women (97%) delivered live birth babies. Due to multiple births, the initial
110 cohort included 2,868 infants. These children and their families have been followed at regular
111 intervals. The 20 year follow-up was the first to assess energy drink intake. Data from this
112 time point, as well as socio-demographic data from earlier assessment points, are reported
113 here. Informed consent was obtained from mothers from enrolment and from adolescents
114 from the age of 16 years. The Raine study protocol was approved by the ethics committees of
115 King Edward Memorial Hospital for Women and Princess Margaret Hospital for Children,
116 Perth Western Australia. Ethical approval for the 20 year follow-up was obtained from the
117 University of Western Australia Human Research Ethics Committee.

118

119 Loss to follow up

120 Full details of cohort attrition have been documented previously.^[26,27] Briefly, families lost to
121 follow up were characterised by greater socioeconomic disadvantage at the time of enrolment
122 (16-20 weeks gestation) compared with families who remained in the study. However, the
123 Raine Study initially over-sampled socially disadvantaged families, meaning that the cohort
124 has tended to become more representative of the Australian population over time. Of the
125 2125 young adults eligible for the 20 year follow-up, 1565 (74%) participated (240 deferred
126 from participating, 517 had withdrawn from the study, 188 were lost to follow-up and 38

127 were deceased). The characteristics of those who participated in the 20 year follow-up
128 compared with those who did not are presented in Table 1.

129

130 **Energy drink consumption (mL/day)**

131 Participants reported their frequency of energy drink consumption in a confidential self-
132 report questionnaire. Response options were: never, <1/month, 1 day/month, 2 days/month, 3
133 days/month, 1 day/week, 2 days/week, 3 days/week, 4 days/week, 5 days/week, 6 days/week
134 and every day. In addition, participants were asked to report the usual amount (total number
135 of cans) they would drink per day on a day that they consumed an energy drink. Frequency
136 and amount data were then used to create a mL/day consumption variable. We based these
137 assumptions on one can containing 250mL of energy drink given the volume capacity of a
138 regular-sized Red Bull® can as Red Bull® is the most popular energy drink by market
139 share.^[1] This was a conservative estimate given that some energy drinks are available in
140 larger can sizes. The energy drink consumption variable (mL/day) was also grouped into the
141 following categories: 0mL/day, <250mL/day and ≥250ml/day).

142

143 **Mental health**

144 Mental health was assessed using the short form of the depression, anxiety and stress scales
145 (DASS-21).^[28] The longer DASS-42 and short-form DASS-21 were developed using
146 Australian data and have been validated in both clinical and non-clinical samples.^[29,30] The
147 DASS-21 is a self-report measure comprised of 21 items that assess symptoms of depression
148 (seven items), anxiety (seven items) and stress (seven items). It yields separate depression,
149 anxiety and stress subscale scores, ~~and a total score that is the sum of the three subscales and~~
150 ~~represents a composite measure of negative emotional symptoms.~~ The depression scale
151 assesses hopelessness, self-deprecation, devaluation of life, lack of interest/involvement,

152 dysphoria, anhedonia, and inertia; the anxiety scale assesses autonomic arousal, skeletal
153 muscle effects, subjective experience of anxious affect and situational anxiety; and the stress
154 scale assesses nervous arousal, difficulty relaxing, being easily upset/agitated, irritable/over-
155 reactive and impatient.^[28] The participant was asked to rate each symptom on the basis of its
156 severity during the previous week. Each item uses a 4-point response scale ranging from 0
157 (did not apply to me at all) to 3 (applied to me very much or most of the time). Scores for
158 each subscale can range from 0 to 21, with higher scores indicating greater depression,
159 anxiety or stress. ~~The total score can range from 0 to 63.~~ These scores were doubled as per
160 the scoring instructions and the scale is referred to as the DASS throughout.

161

162 **Control variables**

163 We adjusted for factors that have a known relationship with energy drink consumption and/or
164 mental health in young adults:

165

166 *Socio-demographic variables*

167 Indices of socio-demographic status were mother's highest level of education at the time of
168 the participant's birth (completed Year 12 high school, yes versus no), maternal age at birth
169 (continuous), family income at birth (<\$7,000, \$7,000-\$11,999, \$12,000-\$23,999, \$24,000-
170 \$35,000 or \$36,000 or more) and the participant's highest level of education (completed Year
171 12 high school, yes versus no) at the time of the 20 year follow-up.

172

173 *Lifestyle factors*

174 *Physical activity and Body Mass Index*

175 At the 20 year follow-up participants were asked how many days they engaged in moderate
176 or vigorous physical activities of at least 10 minute duration during the last seven days.

177 Responses were categorised into <1/week, 1-3 times/week and >3 times/week. A trained
178 research assistant recorded height and weight measurements using standard calibrated
179 equipment. Body Mass Index (BMI) was calculated as body weight (kg) / height (m)² and
180 treated as a continuous variable.

181

182 *Total energy intake and alcohol consumption*

183 Dietary and alcohol intake was assessed at the 20 year follow-up using the self-administered
184 Anti-Cancer Council of Victoria Food Frequency Questionnaire (ACCVFFQ). The
185 ACCVFFQ has been used in a number of large epidemiological studies in Australia and has
186 been assessed for reliability and validity.^[31] Calculation of daily total kilojoule intake and
187 total alcohol (grams of ethanol/day) was performed by the ACCV.

188

189 *Illicit drug use*

190 At the 20 year follow-up, participants were asked in a confidential self-report questionnaire
191 about their use of illicit drugs. Participants reported whether they had tried or ever used the
192 following 10 drugs: marijuana/cannabis, inhalants (glue, petrol), ecstasy, heroin/smack,
193 amphetamines (speed, ice), hallucinogens (acid/LSD), nitrous oxide/nangs, cocaine,
194 methadone, GHB, Ketamine “K”, Benzodiazepines, and Rohypnol; and if so, on average,
195 how often. Response categories were never, only tried once, less than monthly, about
196 monthly, about weekly, daily or don’t know. A binary variable was created to indicate
197 weekly illicit drug use, where an affirmative response to “about weekly”, or “daily” for any
198 of the illicit 10 drugs was coded as weekly illicit drug use.

199

200 **Statistical analysis**

201 Descriptive statistics were computed for socio-demographic variables, physical activity and
202 BMI, total energy intake, alcohol intake and illicit drug use. Chi square and independent
203 sample t-tests were used to identify differences in characteristics between non-participants
204 and participants, and males and females. ~~–~~ To examine associations between energy drink
205 consumption and DASS scores, univariate linear regression models were conducted with
206 DASS scores as the continuous dependent variables of interest and energy drink consumption
207 (mL/day) as the independent variable. These analyses were then repeated with the inclusion
208 of potential confounding variables. Multivariate linear regression models were also used to
209 assess associations between frequency categories of energy drink consumption (i.e., 0mL/day
210 as the reference category, <250mL/day and ≥250ml/day) and DASS scores. Multivariate
211 logistic regression was used to predict being in the highest quartile (vs lowest quartile) of
212 DASS scores. To test whether a linear trend existed between increasing frequency of energy
213 drink consumption and DASS scores, we ran models that contained an ordinal energy drink
214 consumption frequency variable. This ordinal variable was created by assigning values of 0,
215 1, 2 and 3 to persons reporting an energy drink consumption frequency of never, monthly or
216 less, weekly and every day, respectively. No gender interaction effects with mental health
217 outcomes were observed; however analyses were stratified by gender regardless, given the
218 gender differences in energy drink use, with males consuming energy drinks more frequently
219 and in larger quantities than females.^[5,6,32] Furthermore, the relationship between energy
220 drink consumption and depression, anxiety and stress scores were treated as linear as we
221 found no evidence of a curvilinear relationships when we added the square of energy drink
222 consumption to the multivariate linear regression models. SPSS version 20.0 was used for the
223 data analysis.

224

225 **Results**

226 | Descriptive statistics

227 | A total of 1062 participants provided complete mental health data for analysis. Table 2
 228 | summarises descriptive statistics for the socio-demographic characteristics, energy drink
 229 | consumption, lifestyle factors and mental health, by gender. The mean age of study
 230 | participants was 19.98 years (\pm 3.29). Of those who reported they consumed energy drinks
 231 | (n=657, 62% of the sample), 396 (60%) consumed them on a monthly or less basis, 239
 232 | (36%) consumed them weekly and 22 (4%) consumed them every day. Consumption of
 233 | energy drink ranged from 0mL to 1 Litre per day. In terms of DASS scores, 75% of males
 234 | and 67% of females scored within a 'normal' range for depression (i.e., scores between 0 to
 235 | 9), 80% of males and 70% of females scored within a 'normal' range for anxiety (i.e., scores
 236 | between 0 to 7), and 85% of males and 75% of females scored within a 'normal' range for
 237 | stress (i.e., scores between 0 to 14). Since these DASS cut points are not empirically
 238 | validated and are not recommended for use in research, we refer to DASS scores as a
 239 | continuous variable in all result tables, with the exception of our use of quartiles as a
 240 | categorical outcome variable in logistic regression models. DASS scores were skewed, which
 241 | is expected given the non-clinical nature of the sample, but were within the acceptable range
 242 | for psychometric purposes (DASS skewness statistics: ~~Total = 1.57,~~ depression = 1.83,
 243 | anxiety = 1.80 and stress = 1.24). Analyses were run using raw and transformed normalised
 244 | DASS scores and the pattern of results was identical regardless of the method used, for males
 245 | and females. Therefore, we report raw DASS scores in all analyses for ease of interpretation.

246

247 | Linear regression models

248 | Tables 3, 4 and 5 presents univariate and multivariate linear regression results between ~~DASS~~
 249 | ~~scores and~~ energy drink consumption and depression, anxiety and stress, respectively, ~~by~~
 250 | ~~gender.~~ These analyses included all participants regardless of energy drink consumption (i.e.,

251 energy drink drinkers and non-drinkers). We also ran analyses with only those participants
 252 who reported consuming energy drinks (i.e., excluding non-drinkers), and this did not alter
 253 the pattern of the results.

254

255 In univariate analyses (i.e., Model 1 in Tables 3 through 5), energy drink consumption
 256 (100mL/day) was significantly associated with depression (total sample and males but not
 257 females; Table 3) anxiety (total sample and both males and females; Table 4) and stress (total
 258 sample and both males and females; Table 5) scores, ~~stress and total DASS scores in both~~
 259 ~~males and females and higher depression scores in males~~ (all $p < 0.05$). After adjusting for
 260 ~~potential confounding factors~~ sex, maternal education, family income, completion of
 261 secondary school, alcohol and kilojoule intake, physical activity, BMI and illicit drug use
 262 (i.e., Model 2 in Tables 3 through 5) multivariate models in Table 3), energy drink
 263 consumption was significantly associated with ~~higher~~ depression, anxiety, ~~and~~ stress for the
 264 total sample and males ($p < 0.05$) but not females ($p > 0.05$). ~~and total DASS scores in males~~
 265 ~~only.~~ After also further adjusting (i.e., Models 3, 4 and 5), ~~o~~ Only the association
 266 between energy drink consumption and anxiety in males remained significant after adjusting
 267 for co-existing mental health problems (i.e., Model 3, 4 and 5 in Tables 3 through 5) ($\beta =$
 268 0.32; 95% CI = 0.05, 0.58).

269

270 Associations between DASS scores and ~~frequency of categories of~~ energy drink consumption
 271 are presented in Table 6. After adjusting for sex, maternal education, family income,
 272 completion of secondary school, alcohol and kilojoule intake, physical activity, BMI and
 273 illicit drug use, participants who consumed ≥ 250 mL/day of energy drink (compared to
 274 0mL/day) had higher anxiety and stress scores and this was true for the total sample and
 275 males (all $p < 0.05$) but not females ($p > 0.05$). No significant associations were found between

276 these categories of energy drink consumption and depression, for either the whole sample or
277 by gender.

278

279 *Logistic regression models*

280 Table 7 presents the logistic regression results of being in the highest quartile (vs lowest
281 quartile) of DASS scores. For the total sample, energy drink consumption (100mL/day) was
282 associated with an increase in the odds of being in the highest quartile (versus lowest
283 quartile) of depression (OR = 1.15; 95% CI = 1.01, 1.31) and anxiety (OR = 1.17; 95% CI =
284 1.03, 1.30) but not stress scores ($p > 0.05$). In males, energy drink consumption was
285 associated with an increase in the odds of being in the highest quartile (versus lowest
286 quartile) of anxiety (OR = 1.23; 95% CI = 1.03, 1.48) and stress (OR = 1.21; 95% CI = 1.01,
287 1.45) but not depression scores ($p > 0.05$). No significant associations were found between
288 being in the highest quartile (vs lowest quartile) of DASS depression, anxiety or stress scores
289 and energy drink consumption (per 100mL/day) in females.

290

291

292 ~~Males who consumed energy drinks on a daily basis had significantly higher DASS total,~~
293 ~~depression, anxiety and stress scores compared with males who never consumed energy~~
294 ~~drinks. Among males, DASS total, anxiety and stress scores increased with increasing energy~~
295 ~~drink consumption frequency (test for trend all $p < 0.05$). No significant associations or~~
296 ~~increasing relationship between energy drink consumption frequency and DASS scores were~~
297 ~~found among females.~~

298

299 **Discussion**

300 To our knowledge this is the first study to investigate the association between energy drink
301 consumption and mental health in a population-based sample of young adults. Our results
302 suggest a positive association between ~~depression, anxiety, stress and total DASS score~~ and
303 energy drink consumption in young adult males. This relationship remained after adjusting
304 for covariates and the presence of other mental health difficulties. ~~After adjusting for~~
305 ~~covariates, energy drink consumption and frequency of energy drink consumption was~~
306 ~~significantly associated with poor mental health (all DASS subscales) in males but was not~~
307 ~~associated with mental health in females.~~

308

309 Empirical links between energy drink consumption and youth depressive, anxious and stress
310 symptoms are relatively unexplored. However, our findings are consistent with results from
311 two US studies, where consumption of energy drinks were associated with anxiety^[4,24], with
312 symptoms including heart palpitations and “jolt and crash” experiences, with and significant
313 dose effects were identified with~~related to~~ these findings. Our results are also consistent with
314 several small studies with clinical (treatment-seeking) participants. For example, symptoms
315 of severe anxiety have been reported with chronic heavy consumption (six to eight servings
316 daily) of an energy drink, with symptoms subsiding after cessation of use.^[9,21] ~~There have~~
317 ~~also been reports of psychosis temporally associated with energy drink consumption in~~
318 ~~individuals with an existing mental health disorder^[31,32] and in a patient with no history of~~
319 ~~psychiatric illness.^[10] Furthermore, teachers have reported more behavioural issues with~~
320 ~~students who admit that they are drinking energy drinks.^[14]~~ Given our results suggested a
321 specific association with anxiety, future studies may benefit from distinguishing between
322 different aspects of mental health, particularly anxiety versus depression. This study does not
323 support links between energy drink consumption and depressive symptoms, after coexisting
324 anxiety is adjusted for.

325
326

327 There are a number of possible explanations for the relationship between energy drink
328 consumption ~~and and depression, anxiety and stress~~. One is that the ingredients in energy
329 drinks may potentially exacerbate or initiate ~~mental disorder~~anxiety symptoms. Energy drinks
330 contain high levels of caffeine. Caffeine is a pharmacologically active substance that, in small
331 doses, has been associated with positive temporary benefits, such as alertness, feelings of
332 increased energy, improved concentration and memory.^[12] However, caffeine consumption
333 can also have detrimental mental health effects. Studies in adult twins show that ~~lifetime high~~
334 caffeine intake, ~~caffeine toxicity and caffeine dependence are is~~ significantly and positively
335 associated with various psychiatric disorders including generalized anxiety disorder, panic
336 disorder, antisocial personality disorder, major depression, alcohol dependence, and cannabis
337 and cocaine abuse/dependence.^[33] Furthermore, caffeine dependent adolescents score higher
338 on measures of anxiety and depression than their nondependent peers.^[34] ~~Most energy drinks~~
339 ~~also contain large amounts of sugar. Sugar consumption has been found to be related to a~~
340 ~~higher prevalence of depression, possibly through increased level of β -endorphins and~~
341 ~~oxidative stress.~~^[35] Other energy drink ingredients such as guarana and ginseng have been
342 linked to anxiety, irritability, nervousness, restlessness, tremors and mania.^[35] Alternatively,
343 it is possible that the relationship between energy drinks and ~~mental health~~anxiety is bi-
344 directional. That is, individuals ~~experiencing anxiety with mental health issues~~ may use
345 energy drinks to self-medicate for psychiatric symptoms,^[21] such as temporary relief of
346 ~~distress affect related apathy and lethargy~~ or for positive effects on attention and
347 performance.^[12]

348

349 In this sample males consumed larger quantities of energy drinks and consumed energy
350 drinks more frequently, than females. This may be one explanation for the gender differences

351 ~~observed. The difference we observed for gender may be due to males consuming larger~~
352 ~~quantities of energy drinks, and consuming them on a more regular basis than females.~~ Other
353 studies have also reported that energy drink use is more prevalent among males than
354 females.^[5,6,32,36] Energy drink popularity among males may relate to the advertising and
355 marketing of energy drinks, which tend to be targeted toward young males using hyper-
356 masculine images and sponsorship of extreme-style sporting events and rock music.^[37] As
357 this is the first study to investigate associations between energy drink use and mental health
358 in a population-based sample of young adults, replication and extension is important and may
359 help to clarify the nature of any gender differences in these relationships. It is also worth
360 noting that we did not identify significant gender interaction effects. Thus, our findings do
361 not support specific gender differences in the relationship between energy drink consumption
362 and mental health, but simply reflect that such associations were observed at a statistically
363 significant level for males but not females in our sample.

364
365 The present findings have important implications for policymakers, health professionals and
366 the general public. Current Australian regulations (Standard 2.6.4) restrict the amount of
367 caffeine in Australian energy drinks to 320mg per litre and energy drink labels must contain
368 an advisory statement recommending consumption to a limit of 500mL (two cans) a day.^[38]
369 ~~Although only 6% of energy drink drinkers in this study consumed more than 500mL per~~
370 ~~day, it was associated, on average, with an increase of 5 in DASS scores in males relative to~~
371 ~~non-consumption of energy drinks. Furthermore, everyday consumption of energy drinks was~~
372 ~~associated with, on average, an increase of 9 in DASS scores in males relative to non-~~
373 ~~consumption of energy drinks. Our results suggest that generally, the more energy drink~~
374 ~~consumed by young adult males, the more vulnerable they are to experiencing anxiety related~~
375 ~~symptoms.~~ Further research into the possible adverse effects of energy drink use is needed

376 | and consumption guidelines may need to be updated regularly with the latest evidence. ~~The~~
377 | ~~negative effects of energy drinks may be dose dependent with excessive amounts leading to~~
378 | ~~adverse results.~~ Future studies may wish to elucidate whether it is the frequency or the
379 | amount of use, the type of energy drink, the individual or combination of components that
380 | have the greatest impact on mental health.

381

382 | ~~At a national level, policies to discourage regular energy drink use among this age group,~~
383 | ~~such as enforcing industry wide standards for responsible messaging about the purported~~
384 | ~~benefits and possible risks associated with energy drink consumption and limiting~~
385 | ~~advertisements and sales may be needed. Furthermore, studies have shown that price affects~~
386 | ~~food choices among adolescents^[40] so increasing taxes on the production and sales of energy~~
387 | ~~drinks may drive up prices and subsequently reduce consumption in this age group.~~ More
388 | education may be needed to inform young people about the ingredients and potential harms
389 | associated with energy drink consumption. Given that adequate nutrition is essential during
390 | periods of rapid physical development, and that the majority of mental health problems first
391 | manifest in adolescence and early adulthood,^[39] health promotion programs should promote
392 | alternative ways to increase energy levels ~~and improve mood~~ among young adults such as
393 | eating a nutritious diet, getting adequate sleep, engaging in regular physical activity and
394 | seeking professional help. Practicing clinicians may wish to assess energy drink intake in
395 | routine evaluations of mental health, particularly for young males presenting with ~~depressive,~~
396 | anxiety ~~and stress~~ symptoms. Finally, health professionals, parents and peers should be aware
397 | of energy drink use as a possible marker for mental ill health in young people, especially
398 | males.

399

400 | The findings of our study must be interpreted in light of several limitations. Firstly, the data
401 | were cross-sectional. Thus, we cannot draw conclusions regarding the causal direction of the

402 relationships in question. Future research should incorporate prospective, longitudinal study
403 designs. Secondly, we relied on self-reported energy drink use and mental health. Self-report
404 assessment has been established as a valid means for assessing mental health difficulties such
405 as depression, anxiety and stress,^[29,30] and may lead to more truthful reporting than face-to-
406 face assessment, but we cannot rule out the possibility of under- or over-reporting in some
407 cases. Third, we report on *symptoms* of depressive, anxiety and stress, rather than diagnosable
408 depressive or anxiety disorders. Fourth, participants included in the Raine Study 20 year
409 follow-up of were more likely to be socioeconomically advantaged relative to participants
410 lost to follow-up. Thus, care needs to be taken in generalising these results to the wider
411 community. Further research that replicates our results in other cohorts would help to address
412 this. Fifth, we did not collect data on size or brand name of energy drink consumed, on other
413 energy drink products such as the smaller sized and more concentrated ‘energy shots’ or total
414 caffeine consumption from other food and beverage products. However, our estimate of the
415 size of energy drink consumed was conservative and, if anything, research applying more
416 detailed estimates may be expected to reveal stronger relationships. Sixth, and as noted, our
417 results in relation to gender differences must be interpreted with caution as they may be due
418 to a type 1 error, given that there was no significant interaction effect between energy drink
419 consumption and sex in multivariate models. Despite these limitations, the results from our
420 study provide new, important information regarding increased ~~depressive, anxiety and stress~~
421 ~~symptoms~~ with increasing energy drink consumption ~~and frequency~~ among young adult
422 males. To our knowledge, this is the first published study to examine such a relationship in a
423 large population-based cohort.

424

425 **Conclusion**

426 | ~~In conclusion, This our~~ study found that energy drink consumption ~~and frequency~~ was
427 | associated with increased ~~depressive, anxiety and stress~~ symptoms in young adults, ~~especially~~
428 | males. Further research into the possible contribution of energy drink use to the development
429 | of mental health problems in young adults is needed.

430

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444

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533

534 **Table 1 Characteristics of participants included in present study of energy drinks and**
 535 **mental health compared with nonparticipants in the 20 year follow up**

	Participants (n=1062) %	Non-participants (n=1634) %
Maternal age at birth (M[SD])	29.6 (5.7)	27.3 (6.0)***
Maternal BMI ^a (M[SD])	22.2 (4.1)	22.4 (4.4)
Mother drinking alcohol ^a		
Never	50.1	57.1
Less than once a week	35.5	26.5
Approximately once a week	8.5	10.8
Several times a week	5.5	4.9
Daily	0.8	0.7***
Mother smoking cigarettes ^a		
None	80.5	68.4***
1-5 daily	6.6	9.6
6-10 daily	4.8	8.5
11-15 daily	3.9	6.4
16-20 daily	2.6	4.6
21 or more per day	1.6	2.5
Mother completed secondary education ^a	72.3	70.8
Family income ^a		
< \$7,000	5.7	10.4***
\$7,000 - \$11,999	6.5	10.9
\$12,000-\$23,999	21.4	28.9
\$24,000-\$35,000	27.1	23.2
\$35,001 or more	39.4	26.6
Biological father living at home ^a	90.8	84.3***
Offspring gestational age at birth (weeks) (M[SD])	38.8 (2.1)	38.6 (2.5)
Offspring birth weight (kg) (M[SD])	3309.1 (571.9)	3271.7 (648.9)
Preterm birth (<37wks)	8.0	9.6***
Offspring sex - % male	47.0	53.0***

536 * p<0.05, **p<0.01, *** p<0.001

537 ^a in pregnancy, measured at 18 weeks gestation

538

539 **Table 2 Comparison of characteristics by gender of the subjects included in analysis of**
 540 **energy drink consumption and mental health from the Western Australian Pregnancy**
 541 **Cohort (Raine) at 20 years (n=1062)**
 542

	Males (n=498)	Females (n=564)
	% or mean (SD)	% or mean (SD)
Socio-demographics		
Maternal education ^a < Year 12	28	28
Maternal age at birth (M[SD])	29 (6)	30 (6)
Family income ^a		
< \$7,000	6	6
\$7,000 - \$11,999	6	7
\$12,000-\$23,999	21	22
\$24,000-\$35,000	29	25
\$35,001 or more	39	40
Completed high school	77	84**
Energy drink consumption		
Estimated energy drink quantity (mL/day) (M[SD])	51 (116)	36 (91)*
Frequency of energy drink consumption		
Never	35	41**
Monthly or less	35	39
Weekly	27	18
Everyday	3	2
Lifestyle factors		
Alcohol intake (g/day) (M[SD])	19 (21)	13 (15)***
Kilojoule intake (KJ/day) (M[SD])	10,180 (4513)	7072 (3687)***
Physical activity		
<1 day/week	10	24***
1-3 days/week	16	28
>3days/week	74	48
BMI (kg/m ²) (M[SD])	24 (5)	24 (6)
Weekly illicit drug use	14	10*
Mental health		
DASS Depression scale total (M[SD]) ^b	6 (7)	8 (8)***
DASS Anxiety scale total (M[SD]) ^b	4 (5)	6 (6)***
DASS Stress scale total (M[SD]) ^b	7 (7)	10 (8)***
DASS Total (M[SD])^e	18 (17)	24 (21)***

543 * p<0.05, **p<0.01, *** p<0.001

544 ^ain pregnancy, measured at 18 weeks gestation

545 ^bScores have a possible range of 0 to 42, with higher scores indicating greater depression,
 546 anxiety or stress.

547 ^eTotal scores have a possible range of 0 to 126.

Table 3 Univariate and multivariate linear regression coefficients for DASS scores and energy drink consumption^a

	DASS Depression β (95%CI)	DASS Anxiety β (95%CI)	DASS Stress β (95%CI)	DASS Total β (95%CI)
MALES				
Single model (n=498)				
Energy drink consumption (100mL/day)	0.81 (0.26, 1.36)**	0.74 (0.39, 1.09)***	1.09 (0.54, 1.64)***	2.64 (1.37, 3.91)***
Multivariate model^a (n=442)				
Energy drink consumption (100mL/day)	0.76 (0.17, 1.35)*	0.79 (0.42, 1.15)***	1.15 (0.56, 1.73)***	2.69 (1.33, 4.05)***
FEMALES				
Single model (n=564)				
Energy drink consumption (100mL/day)	0.72 (-0.04, 1.49)	0.63 (0.04, 1.21)*	0.82 (0.06, 1.59)*	2.17 (0.29, 4.05)*
Multivariate model^a (n=499)				
Energy drink consumption (100mL/day)	0.37 (-0.43, 1.16)	0.24 (-0.37, 0.85)	0.40 (-0.41, 1.21)	1.01 (-0.94, 2.96)

*p<0.05, **p<0.01, ***p<0.001

^aAnalysis adjusted for maternal education, family income, completion of secondary school, alcohol intake, kilojoule intake, physical activity, BMI and illicit drug use

Table 4 Multivariate linear regression coefficients for DASS scores and frequency of energy drink consumption

	DASS Depression β (95%CI)	DASS Anxiety β (95%CI)	DASS Stress β (95%CI)	DASS Total β (95%CI)
Energy drink consumption frequency				
<i>Reference category = never</i>				
MALES				
Everyday	7.83 (2.83, 12.84)**	8.30 (5.26, 11.33)***	11.70 (6.78, 16.63)***	27.83 (16.43, 39.23)***
Weekly	0.53 (-1.29, 2.36)	1.01 (-0.10, 2.11)	0.77 (-1.02, 2.57)	2.31 (-1.84, 6.47)
Monthly or less	-0.55 (-2.20, 1.10)	-0.23 (-1.23, 0.77)	0.25 (-1.38, 1.87)	-0.53 (-4.29, 3.23)
FEMALES				
Everyday	1.38 (-4.50, 7.25)	2.37 (-2.11, 6.85)	4.26 (-1.67, 10.20)	8.01 (-6.37, 22.39)
Weekly	0.04 (-2.02, 2.09)	-0.50 (-2.06, 1.07)	0.59 (-1.48, 2.67)	0.13 (-4.89, 5.15)
Monthly or less	-0.04 (-1.67, 1.60)	0.30 (-0.95, 1.54)	0.70 (-0.95, 2.35)	0.96 (-3.03, 4.95)

*p<0.05, **p<0.01, ***p<0.001

^aAnalysis adjusted for maternal education, family income, completion of secondary school, alcohol intake, kilojoule intake, physical activity, BMI and illicit drug use

Table 3 Linear regression coefficients for DASS depression scores and frequency of energy drink consumption (per 100ml/day)

	DASS depression				
	<u>Model 1^a</u>	<u>Model 2^b</u>	<u>Model 3^c</u>	<u>Model 4^d</u>	<u>Model 5^e</u>
<u>All participants</u>					
<u>Energy drink consumption (100mL/day)</u>	<u>0.70 (0.24, 1.16)**</u>	<u>0.63 (0.14, 1.11)*</u>	<u>0.10 (-0.28, 0.48)</u>	<u>0.05 (-0.31, 0.40)</u>	<u>-0.03 (-0.37, 0.31)</u>
<u>Males</u>					
<u>Energy drink consumption (100mL/day)</u>	<u>0.81 (0.26, 1.36)**</u>	<u>0.76 (0.17, 1.35)*</u>	<u>-0.03 (-0.50, 0.45)</u>	<u>-0.03 (-0.47, 0.42)</u>	<u>-0.17 (-0.60, 0.25)</u>
<u>Females</u>					
<u>Energy drink consumption (100mL/day)</u>	<u>0.72 (-0.04, 1.49)</u>	<u>0.37 (-0.43, 1.16)</u>	<u>0.17 (-0.45, 0.80)</u>	<u>0.10 (-0.49, 0.69)</u>	<u>0.09 (-0.47, 0.65)</u>

p<0.10, *p<0.05, **p<0.01, *** p<0.001

^aUnadjusted

^bAdjusted for sex, maternal education, family income, completion of secondary school, alcohol intake, kilojoule intake, physical activity, BMI and illicit drug use

^cAdjusted for Model 2 plus DASS anxiety

^dAdjusted for Model 2 plus DASS stress

^dAdjusted for Model 2 plus DASS anxiety and DASS stress

Table 4 Linear regression coefficients for DASS anxiety scores and frequency of energy drink consumption (per 100ml/day)

	<u>DASS Anxiety</u>				
	<u>Model 1^a</u>	<u>Model 2^b</u>	<u>Model 3^c</u>	<u>Model 4^d</u>	<u>Model 5^e</u>
<u>All participants</u>					
<u>Energy drink consumption (100mL/day)</u>	<u>0.63 (0.30, 1.0)***</u>	<u>0.60 (0.26, 0.95)**</u>	<u>0.32 (0.05, 0.59)*</u>	<u>0.18 (-0.07, 0.43)</u>	<u>0.17 (-0.07, 0.41)</u>
<u>Males</u>					
<u>Energy drink consumption (100mL/day)</u>	<u>0.74 (0.39, 1.09)***</u>	<u>0.79 (0.42, 1.15)***</u>	<u>0.50 (0.21, 0.79)**</u>	<u>0.31 (0.03, 0.59)*</u>	<u>0.32 (0.05, 0.58)*</u>
<u>Females</u>					
<u>Energy drink consumption (100mL/day)</u>	<u>0.63 (0.04, 1.21)*</u>	<u>0.24 (-0.37, 0.85)</u>	<u>0.06 (-0.41, 0.54)</u>	<u>0.03 (-0.41, 0.47)</u>	<u>0.01 (-0.41, 0.43)</u>

p<0.10, *p<0.05, **p<0.01, *** p<0.001

^aUnadjusted

^bAdjusted for sex, maternal education, family income, completion of secondary school, alcohol intake, kilojoule intake, physical activity, BMI and illicit drug use

^cAdjusted for Model 2 plus DASS depression

^dAdjusted for Model 2 plus DASS stress

^dAdjusted for Model 2 plus DASS depression and DASS stress

Table 5 Linear regression coefficients for DASS stress scores and frequency of energy drink consumption (per 100ml/day)

	DASS Stress				
	<u>Model 1^a</u>	<u>Model 2^b</u>	<u>Model 3^c</u>	<u>Model 4^d</u>	<u>Model 5^e</u>
All participants					
<u>Energy drink consumption (100mL/day)</u>	<u>0.63 (0.30, 1.0)***</u>	<u>0.60 (0.26, 0.95)**</u>	<u>0.43 (0.67, 0.79)*</u>	<u>0.27 (-0.09, 0.63)</u>	<u>0.23 (-0.09, 0.55)</u>
Males					
<u>Energy drink consumption (100mL/day)</u>	<u>1.09 (0.54, 1.64)***</u>	<u>1.15 (0.56, 1.73)***</u>	<u>0.64 (0.20, 1.07)**</u>	<u>0.31 (-0.14, 0.75)</u>	<u>0.32 (-0.08, 0.72)</u>
Females					
<u>Energy drink consumption (100mL/day)</u>	<u>0.82 (0.06, 1.59)*</u>	<u>0.40 (-0.41, 1.21)</u>	<u>0.15 (-0.04, 0.74)</u>	<u>0.18 (-0.40, 0.76)</u>	<u>0.11 (-0.42, 0.64)</u>

p<0.10, *p<0.05, **p<0.01, *** p<0.001

^aUnadjusted

^bAdjusted for sex, maternal education, family income, completion of secondary school, alcohol intake, kilojoule intake, physical activity, BMI and illicit drug use

^cAdjusted for Model 2 plus DASS depression

^dAdjusted for Model 2 plus DASS anxiety

^dAdjusted for Model 2 plus DASS depression and DASS anxiety

Table 6 Multivariate linear regression coefficients for DASS scores and frequency of energy drink consumption (categorical)

	<u>DASS Depression</u> <u>β (95%CI)</u>	<u>DASS Anxiety</u> <u>β (95%CI)</u>	<u>DASS Stress</u> <u>β (95%CI)</u>
<u>Energy drink consumption</u>			
<u>Reference category = 0mL/day</u>			
<u>All participants</u>			
<u>< 250mL/day (n=294)</u>	<u>0.02 (-1.05, 1.09)</u>	<u>0.12 (-0.64, 0.89)</u>	<u>0.57 (-0.53, 1.67)</u>
<u>≥ 250mL/day (n=29)</u>	<u>1.89 (-0.64, 4.42)</u>	<u>2.19 (0.39, 4.00)*</u>	<u>3.25 (0.66, 5.84)*</u>
<u>Males (n=498)</u>			
<u>< 250mL/day (n=294)</u>	<u>-0.04 (-1.56, 1.48)</u>	<u>0.37 (-0.58, 1.31)</u>	<u>0.57 (-0.94, 2.08)</u>
<u>≥ 250mL/day (n=29)</u>	<u>2.11 (-1.08, 5.30)</u>	<u>2.26 (0.29, 4.24)*</u>	<u>3.56 (0.39, 6.73)*</u>
<u>Females (n=564)</u>			
<u>< 250mL/day (n=314)</u>	<u>-0.02 (-1.53, 1.48)</u>	<u>0.03 (-1.12, 1.18)[#]</u>	<u>0.69 (-0.83, 2.21)</u>
<u>≥ 250mL/day (n=20)</u>	<u>0.87 (-3.17, 4.90)</u>	<u>1.48 (-1.60, 4.56)</u>	<u>2.00 (-2.08, 6.08)</u>

*p<0.05, **p<0.01, *** p<0.001

^aAnalysis adjusted for sex, maternal education, family income, completion of secondary school, alcohol intake, kilojoule intake, physical activity, BMI and illicit drug use

Table 7 Results of logistic regression analysis to predict being in the highest quartile (vs lowest quartile) of DASS scores

	<u>Depression</u> <u>(quartile 4 vs 1)^a</u> <u>OR (95%CI)</u>	<u>Anxiety</u> <u>(quartile 4 vs 1)^a</u> <u>OR (95%CI)</u>	<u>Stress</u> <u>(quartile 4 vs 1)^a</u> <u>OR (95%CI)</u>
<u>Energy drink consumption</u>			
<u>(100mL/day)</u>			
<u>All participants</u>	<u>1.15 (1.01, 1.31)*</u>	<u>1.17 (1.03, 1.3)*</u>	<u>1.12 (0.98, 1.29)#</u>
<u>Males</u>	<u>1.17 (0.98, 1.40)#</u>	<u>1.23 (1.03, 1.48)*</u>	<u>1.21 (1.01, 1.45)*</u>
<u>Females</u>	<u>0.11 (0.90, 1.38)</u>	<u>1.07 (0.87, 1.32)</u>	<u>1.01 (0.82, 1.25)</u>

#p<0.10, *p<0.05, **p<0.01, *** p<0.001

^aAnalysis adjusted for sex, maternal education, family income, completion of secondary school, alcohol intake, kilojoule intake, physical activity, BMI and illicit drug use