Energy drink intake and metabolic syndrome: a prospective investigation in young adults

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ABSTRACT

Background and Aims: There are concerns that energy drinks (EDs) are contributing to upward trends in overweight, obesity, and cardiometabolic conditions in young people. We investigated cross-sectional and prospective associations between frequency of ED-intake in young-adults and (i) body mass index (BMI) and (ii) Metabolic Syndrome (MetS) and its components.

Methods and Results: Participants from the Raine Study at 20-years (n=1 236) and 22 years (n = 1 117) self-reported ED-intake, dietary intake, and physical activity, and had blood and anthropometric measures taken. Regression modelling examined associations between ED-intake and BMI, MetS and its components.

There was a positive, but not significant, cross-sectional association with BMI and likelihood of MetS with frequent ED use at 20-years (BMI: β=0.19; MetS: OR=1.11) and 22-years (BMI: β=0.51; MetS: OR=1.28). There were no associations in the prospective analysis.

After adjustment, significant associations existed between occasional ED-intake and lower HDL-cholesterol (β=-0.07) and higher fasting triglycerides (β=0.16) at 20-years, and lower fasting triglycerides at 22-years (β=-0.10), but no significant associations in the prospective analyses.

Conclusion: No significant associations existed between frequency of ED-intake, and BMI, MetS or its individual components over two years (ages 20-22 years). Future studies should include volume of EDs consumed and longer follow-up.

Keywords: EDs, young adults, metabolic syndrome, BMI, obesity, blood pressure, triglycerides, cholesterol, glucose

INTRODUCTION

Energy Drinks (EDs) play a dominant role in the beverage market, with a global value projected to increase from US$43 billion in 2016 to US$72 billion by 2024 (1, 2). They are attractively packaged and heavily marketed at events which appeal to youth, such as sporting events and rock concerts. Approximately one-quarter of young-adults report consuming them at least weekly, often in quantities in excess of 500mL per day (3, 4).

Whilst marketed to boost mental and physical performance, EDs have been associated with a number of adverse health-effects including psychological and physiological problems (5, 6). The calorie and sugar content in standard full-sugar EDs (i.e. not low calorie/sugar formulations) are comparable to sugar-sweetened soft-drinks, which have been associated with overweight/obesity, chronic metabolic diseases and dental caries (7). In Australia, EDs provide around 160mg/500mL of caffeine, equivalent to two-cups of instant-coffee. Caffeine has been associated with deleterious metabolic health effects including decreased insulin sensitivity (8) and increased blood-pressure (9).

There is concern EDs are contributing to upward trends in overweight/obesity in young-people and to higher rates of cardiometabolic conditions including the 'Metabolic Syndrome (MetS)' (a cluster of cardiometabolic risk-factors including diabetes and raised fasting plasma glucose, abdominal obesity, dyslipidaemia and high blood-pressure) (10). The aim of our study was to investigate cross-sectional and prospective associations between frequency of ED-intake and: (i) body mass index (BMI); and (ii) presence of the MetS and its individual components, in participants from the Western Australian Pregnancy Cohort (Raine) Study at 20 and 22-years of age.

METHOD

Participants

Our study draws data from the Raine Study Gen2 participants at both 20-years (2010-2012, the first time ED-intake was measured) and at 22-years (2012-2014) (11, 12). The University of Western Australia (RA/4/1/5202) and Curtin University (HR67/2013) provided ethical approval and all participants provided written informed consent (13).

ED-intake

At both ages (20- and 22- years), participants completed a confidential questionnaire in which they self-reported frequency of ED-intake via 12 response options ranging from 'never' to 'everyday', subsequently grouped into three intake-levels: none/rare (never to ≤once/month); occasional (>once/month to <once/week); and frequent (≥once/week).

Biochemistry

PathWest Laboratories analysed fasting blood samples for serum glucose, insulin, triglycerides, total-cholesterol, HDL-cholesterol, and calculated LDL-cholesterol using standardised assays (14).

Anthropometry

Trained staff measured participant's height and weight (to calculate BMI), waist-circumference and blood-pressure. A Dinamap recorder automatically logged blood-pressure every two-minutes, with the average of the second and subsequent readings for both systolic and diastolic used in analysis.

Metabolic Syndrome

MetS was assessed using the International Diabetes Foundation definition and cut-off values (10) and considered present if a participant had central obesity plus two of the following: raised-triglycerides (≥1.7mmol/L) or treatment for lipid abnormality, reduced HDL-cholesterol (≥1.03mmol/L males, ≥1.29mmol/L females), raised blood-pressure (systolic≥130mmHg or ≥85mmHg) or treatment for hypertension, raised fasting plasma glucose (≥5.6mmol/L) or diagnosed Type 2-diabetes.

Adjustment (confounding) variables

These included household income and mother's educational qualification-level at-birth; highest education-level completed and smoking status. Alcohol consumption (g/day ethanol), a "Healthy" or "Western" dietary-pattern z-score (15) and total energy-intake (kJ/week) were measured via the self-administered Anti-Cancer Council of Victoria Food Frequency Questionnaire (16); and physical activity (met-mins/week) via the short-form International Physical Activity Questionnaire (17).

Statistical analysis methods

Regression modelling undertaken in 2018 estimated the effect of frequency of ED-intake on all outcome variables. Cross-sectional analyses were conducted at 20- and 22-years, in addition to prospective analyses which used outcome variables at 22-years and predictors at 20-years, controlling for the same outcome at 20-years. All analyses were adjusted for confounding variables.

RESULTS

Sample characteristics are presented in Table 1. At 20-years (n=1236), 53.4% of participants had none/rare ED-intake, 23.1% occasional and 23.5% frequent, 6.7% had MetS and mean BMI was 24.5±5.10. At 22-years (n=1117), 65.7% of participants had none/rare ED-intake, 17.0% occasional and 17.4% frequent, 9.7% had MetS and mean BMI was 25.3±5.5.

Insert Table 1 here

Cross-sectional and prospective associations between ED-intake and BMI, MetS and its individual components at 20- and 22-years are shown in Table 2. There was a positive, but not statistically significant, association between BMI and frequent ED-intake compared to rare intake at both 20-years (adjusted β=0.19, 95%CI: -0.66, 1.06) and 22-years (adjusted β=0.51, 95%CI: -0.53, 1.55). Frequency of ED-intake was not associated with BMI in the prospective analysis.

Insert Table 2 here

There were higher, but not statistically significant, likelihoods of MetS in the frequent ED-intake group compared to rare intake at both 20-years (adjusted OR=1.11, 95%CI: 0.57, 2.19) and 22-years (adjusted OR=1.28, 95%CI: 0.71, 2.30) (Table 2). Frequency of ED-intake was not associated with MetS in the prospective analysis.

After adjustment, there were significant effects of ED-intake in cross-sectional analyses but not in prospective analyses. Occasional ED-intake was associated with lower HDL-

cholesterol (β=-0.07, 95%CI: -0.13, -0.02, P=0.006) and higher fasting triglycerides (β=0.16, 95%CI: -0.06, -0.26, P=0.002) at 20-years and lower fasting triglycerides at 22-years (β=-0.10, 95%CI: -0.20, -0.01, P=0.034).

DISCUSSION

Our results suggest a positive cross-sectional association between frequency of ED-intake in young-adults aged 20 and 22-years and BMI, MetS and its individual components. However, these were not statistically significant after adjustment for confounding factors, with the exception of lower HDL-cholesterol and higher fasting triglycerides for occasional ED-intake at 20-years and lower fasting triglycerides for occasional ED-intake at 22-years. These associations need to be treated with caution given the number of analyses conducted.

Our findings contrast with other studies which have repeatedly shown sugar-sweetened beverages (SSBs) to be longitudinally associated with overweight/obesity, Type-2 diabetes and MetS (18). Importantly, however, these studies tend to be of a duration of four-years or longer which allows for the development and detection of diet related chronic illness (18). Thus, our study's duration of two-years may have been inadequate to see significant changes, particularly when the study cohort was young and MetS rates increase with age (19). Furthermore, the current study only investigated frequency of ED-intake and there may be other important factors to consider in future studies; such as volume and concurrent activities/behaviours that may be impacting on metabolism (e.g. EDs consumed before, during or after meals and/or exercise).

It is also plausible that the ingredients within EDs (i.e., high-levels of caffeine, amino-acids and herbal extracts) may affect metabolism differently than other SSBs and may diminish some of the negative effects of sugar and caffeine on cardiometabolic health. For example, the amino-acid taurine, commonly found in EDs, has been shown to have cardio-protective effects for human diseases such as hypertension, coronary-artery-disease, high-cholesterol, and myocardial function (20).

Despite the limitations of our study, it is among the first to provide a prospective analysis of frequency of ED-intake and a range of cardio-metabolic measures over two-years. It included a large, population-based sample of young-adults, incorporated objective measures of outcome variables and adjusted for a wide-range of possible confounding factors.

CONCLUSION

Our study did not find compelling evidence of a cross-sectional or prospective association between frequency of ED-intake, BMI, the MetS and its individual components in young-adults over a two-year period. Future studies should include volume of ED consumed and a longer follow-up duration.

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296 **Table 1: Sample characteristics at 20 (n=1236) and 22-years (n=1117) stratified by**
297 **energy drink intake**

		Energy drink intake					
		None or rare [a]		Occasional [b]		Frequent [c]	
		20 year Mean (SD)	22 year Mean (SD)	20 year Mean (SD)	22 year Mean (SD)	20 year Mean (SD)	22 year Mean (SD)
Waist circumference average (cm)		79.2 (13.1)	82.8 (14.6)	79.2 (11.2)	82.8 (12.4)	81.4 (13.8)	86.8 (13.5)
Body Mass Index (kg/m^2)		24.3 (5.3)	25.2 (5.9)	24.1 (4.3)	24.8 (4.7)	24.7 (5.4)	26.2 (5.3)
Systolic Blood Pressure (mmHg)		119.7 (14.3)	121.6 (12.4)	120.1 (15.5)	123.1 (11.9)	122.7 (15.6)	126.4 (13.0)
Diastolic Blood Pressure (mmHg)		66.2 (8.9)	68.7 (8.9)	66.9 (8.3)	69.7 (8.2)	66.5 (8.5)	68.7 (8.8)
Plasma Glucose (mmol/L)		4.91 (0.44)	4.94 (0.41)	4.93 (0.39)	5.02 (0.49)	5.03 (0.45)	5.04 (0.42)
Triglycerides (mmol/L)		1.00 (0.49)	1.1 (0.52)	1.15 (0.69)	1.04 (0.48)	1.13 (0.60)	1.20 (0.55)
High density lipoprotein (mmol/L)		1.37 (0.35)	1.38 (0.36)	1.31 (0.30)	1.35 (0.31)	1.28 (0.28)	1.29 (0.29)
Alcohol (g/day)		12.15 (15.61)	12.5 (15.7)	18.69 (18.56)	19.4 (17.8)	22.07 (20.90)	23.2 (22.7)
Physical activity (mins/week)		3345 (3417)	3564 (3426)	3649 (3881)	3344 (3119)	4587 (4299)	4571 (4539)
Energy intake (ex. alcohol) (kJ/day)		8123 (3078)	7699 (4161)	8700 (3237)	8573 (3553)	9788 (3741)	9935 (5175)
Western Dietary Pattern Score		-0.41 (0.85)	-0.37 (1.28)	-0.22 (0.92)	-0.08 (1.04)	0.15 (1.13)	0.41 (1.69)
Healthy Dietary Pattern Score		-0.13 (0.69)	-0.06 (0.79)	-0.24 (0.64)	-0.11 (0.85)	-0.43 (0.65)	-0.33 (0.75)
		N	**%**	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**
Metabolic Syndrome	Yes	38	6.7	55	9.2	13	5.3	14	8.7	22	8.5	23	13.8
	No	527	93.3	541	90.8	230	94.7	147	91.3	237	91.5	144	86.2
Central Obesity	Yes	136	23.2	173	28.3	51	20.3	46	27.7	66	24.8	61	35.5
	No	450	76.8	439	71.7	200	79.7	120	72.3	200	75.2	111	64.5
Raised Systolic Blood Pressure (≥130mmHg)	Yes	152	25.8	159	26	71	28.2	46	27.7	87	32.7	74	43.3
	No	438	74.2	453	74	181	71.8	120	72.3	179	67.3	97	56.7
Raised Diastolic Blood Pressure (≥85mmHg)	Yes	18	3.1	32	5.2	7	2.8	9	5.4	3	1.1	7	4.1
	No	571	96.9	580	94.8	245	97.2	157	94.6	263	98.9	164	95.9
Raised Fasting glucose (>5.6mmol/L)	Yes	30	5.9	29	5.1	12	5.5	8	5.2	21	9.0	12	7.7
	No	478	94.1	538	94.9	205	94.5	145	94.8	212	91.0	143	92.3
Raised Triglycerides (>1.7mmol/L)	Yes	43	8.5	66	11.6	28	12.9	13	8.5	28	12.0	27	17.4
	No	465	91.5	501	88.4	189	87.1	140	91.5	205	88.0	128	82.6
Reduced HDL (<1.29mmol/L males)	Yes	139	27.4	155	27.3	68	31.3	34	22.2	74	31.8	37	23.9
	No	369	72.6	412	72.7	149	68.7	119	77.8	159	68.2	118	76.1
Income[d]	Higher	435	67.4	495	69.1	195	70.7	121	66.1	184	64.6	119	63.6
	Lower	210	32.6	221	30.9	81	29.3	62	33.9	101	35.4	68	36.4
Mother - post school qualification	Yes	414	62.7	462	63.1	165	57.9	109	57.7	145	49.8	95	49.0
	No	246	37.3	270	36.9	120	42.1	80	42.3	146	50.2	99	51.0
Completed post school education	Yes	185	28.1	384	53.4	75	26.3	94	50.5	85	29.4	82	43.9
	No	474	71.9	335	46.6	210	73.7	92	49.5	204	70.6	105	67.0
Smoker	Yes	65	9.9	85	11.6	35	12.3	30	15.9	80	27.5	64	33.0
	No	594	90.1	646	60.1	250	87.7	159	84.1	211	72.5	130	67.0
Sex	Male	276	41.8	292	39.9	130	45.6	98	51.9	170	58.4	128	64.9
	Female	384	58.2	440	60.1	155	54.4	91	48.1	121	41.6	68	35.1

[a] ≤once/month;
[b] >once/month to <once/week;
[c] ≥once/week;
[d]lower=AUD$0-$35,999/annum, higher=AUD≥$36,000/annum in 1989-1991)

298

Table 2: Associations between energy drink intake and BMI, MetS and components at 20 & 22 years

		Cross-sectional Associations				Prospective Associations	
		20 years		22 years			
	Energy Drink Frequency [b]	Unadjusted Effect size (95% CI)	Adjusted [a] Effect size (95% CI)	Unadjusted Effect size (95% CI)	Adjusted [a] Effect size (95% CI)	Unadjusted Effect size (95% CI)	Adjusted [a] Effect size (95% CI)
BMI (kg/m^2)	Frequent [c]	0.42 (-0.33-1.17)	0.19 (-0.66 – 1.06)	**0.99 (0.05-1.94)**	0.51 (-0.53 – 1.55)	0.14 (-0.22-0.50)	-0.10 (-0.50 – 0.31)
	Occasional [d]	-0.19 (-0.96-0.58)	-0.16 (-0.98 – 0.66)	-0.48 (-1.44-0.48)	-0.61 (-1.58 – 0.37)	0.17 (-0.20-0.53)	0.11 (-0.28 – 0.51)
Metabolic syndrome (Odds Ratio)	Frequent [c]	1.28 (0.75-2.23)	1.11 **(**0.57 – 2.19)	1.57 (0.93-2.64)	1.28 (0.71 – 2.30)	1.53 (0.83-2.82)	1.04 (0.51 – 2.11)
	Occasional [d]	0.78 (0.41-1.50)	0.88 (0.44 – 1.76)	0.94 (0.51-1.73)	0.79 (0.41 – 1.52)	1.35 (0.70-2.59)	1.27 (0.62 – 2.63)
Waist Circumference (cm)	Frequent [c]	**2.21 (0.35-4.08)**	0.54 (-1.56 – 2.63)	**4.01 (1.63-6.39)**	1.26 (-1.32 – 3.84)	0.54 (-0.74-1.82)	-0.26 (-1.71 – 1.19)
	Occasional [d]	-0.02 (-1.93-1.88)	-0.38 (-2.38 – 1.62)	-0.01 (-2.42-2.41)	-0.97 (-3.39 – 1.45)	0.32 (-0.97-1.62)	0.27 (-1.12 – 1.66)
Systolic BP (mm Hg)	Frequent [c]	**3.01 (0.85-5.17)**	0.52 (-1.75 – 2.79)	**4.75 (2.64-6.85)**	1.86 (-0.31 – 4.03)	1.71 (-0.09-3.52)	0.38 (-1.60 – 2.36)
	Occasional [d]	0.40 (-1.80-2.60)	-0.25 (-2.41 – 1.91)	1.44 (-0.69-3.57)	0.23 (-1.81 – 2.27)	1.22 (-0.60-3.03)	0.80 (-1.09 – 2.69)
Diastolic BP (mm Hg)	Frequent [c]	0.33 (-0.92-1.59)	-0.23 (-1.68 – 1.23)	0.06 (-1.44-1.55)	-0.56 (-2.23 – 1.11)	0.52 (-0.87-1.91)	0.10 (-1.48 – 1.68)
	Occasional [d]	0.68 (-0.60-1.96)	0.72 (-0.66 – 2.11)	1.02 (-0.46-2.53)	0.80 (-0.76 – 2.36)	0.68 (-0.73-2.08)	0.63 (-0.89 – 2.15)
Fasting glucose (mmol/L)	Frequent [c]	**0.11 (0.05-0.18)**	0.02 (-0.06 – 0.09)	**0.10 (0.02-0.17)**	0.05 (-0.04 – 0.13)	-0.02 (-0.09-0.05)	-0.02 (-0.10 – 0.05)
	Occasional [d]	0.02 (-0.05-0.09)	-0.01 (-0.08 – 0.06)	**0.08 (0.003-0.16)**	0.06 (-0.02 – 0.14)	-0.03 (-0.10-0.04)	-0.01 (-0.08 – 0.06)
Fasting triglycerides (mmol/L)	Frequent [c]	**0.12 (0.04-0.21)**	0.09 (-0.01 – 0.20)	**0.10 (0.01-0.19)**	0.05 (-0.05 – 0.15)	0.03 (-0.05-0.01)	-0.02 (-0.10 – 0.07)
	Occasional [d]	**0.15 (0.06-0.24)**	**0.16 (0.06 – 0.26)**	-0.06 (-0.16-0.03)	**-0.10 (-0.20 - -0.01)**	-0.02 (-0.09-0.06)	-0.03 (-0.11 – 0.05)
HDL cholesterol (mmol/L)	Frequent [c]	**-0.08 (-0.13- -0.032)**	-0.05 (-0.11 – 0.004)	-0.09 (-0.15- -0.02)	-0.01 (-0.07 – 0.05)	**-0.05 (-0.09- -0.01)**	-0.03 (-0.07 – 0.02)
	Occasional [d]	**-0.06 (-0.11- -0.01)**	**-0.07 (-0.13 - -0.02)**	-0.029 (-0.09-0.03)	-0.01 (-0.06 – 0.05)	-0.03 (-0.07- -0.01)	-0.02 (-0.06 - 0.02)

BMI: body mass index; BP: blood pressure

Boldface indicates statistical significance ($p<0.05$)

[a] Adjusted for gender, family income, mother's education, education completed, smoking, alcohol, total energy intake, physical activity and dietary pattern

[b] Reference category = none or ≤ once per month

[c] Frequent energy drink use defined as ≥ once/week

[d] Occasional energy drink use defined as >once/month to <once/week