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Usual dietary anthocyanin intake, sources and their association with blood pressure in a representative sample of Australian adults

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Abstract

Background: Anthocyanins represent an important subgroup of non-nutritive components of food as evidence continues to build related to their beneficial bioactive effects. Using a recently developed Australian anthocyanin database, the present study aimed to estimate the intake of both total anthocyanins and their subclasses, identify food sources of anthocyanins, and determine associations between anthocyanin intake and measured blood pressure (BP).

Methods: The present study comprised was a secondary analysis of the 2011-12 National Nutrition and Physical Activity component of the Australian Health Survey. Anthocyanin intake was estimated using an Australian anthocyanin database. Usual anthocyanin intake, as estimated from 24-h diet recall data, was computed using multiple source methods, whereas food sources were determined by calculating contribution of food groups to total anthocyanin intake. Regression analysis, adjusted for covariates (age, gender, body mass index, high BP) diagnosis, smoking status and physical activity) assessed the relationship between anthocyanin intake and BP in adults aged ≥ 50 years.

Results: Mean anthocyanin intake was 24.17 ± 0.32 mg day⁻¹. Across age groups, berries were the top sources: blackberry (5-65%), cherry (2-24%), blueberry (2-13%) and raspberry (3-12%). There was a significant inverse association between anthocyanin intake and systolic BP ($\beta = -0.04$, $F = 16.8$, $d.f. = 6$, $r^2 = 0.05$, $P < 0.01$) and diastolic BP ($\beta = 0.01$, $F = 5.35$, $d.f. = 6$, $R^2 = 0.013$, $P < 0.01$), in models that adjusted for covariates.

Conclusions: In comparison with the world composite database, anthocyanin intake in the Australian population was above average [mean (SD): $24.17 (0.32)$ mg day⁻¹ versus $18.05 (21.14)$ mg day⁻¹]. Berries comprised up the primary source of anthocyanins. Anthocyanin intake in older adults aged ≥ 50 years was inversely associated with BP.

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Usual dietary anthocyanin intake, sources and their association with blood pressure in a representative sample of Australian adults

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1 **Abstract**

2 **Background:** Anthocyanins represent an important sub-group of non-nutritive components of
3 food as evidence continues to build related to their beneficial bioactive effects.

4 **Objectives:** Using a recently developed Australian anthocyanin database, this study aimed to
5 estimate the intake of both total anthocyanins and their subclasses, identify food sources of
6 anthocyanins, as well as determine associations between anthocyanin intake and measured
7 Blood Pressure (BP).

8 **Methods:** This was a secondary analysis of the 2011-12 National Nutrition and Physical
9 Activity component of the Australian Health Survey. Anthocyanin intake was estimated using
10 an Australian anthocyanin database. Usual anthocyanin intake estimated from 24-h diet recall
11 data was computed using Multiple Source Methods, while food sources were determined by
12 calculating contribution of food groups to total anthocyanin intake. Regression analysis,
13 adjusted for covariates (age, gender, body mass index, high blood pressure (BP) diagnosis,
14 smoking status and physical activity) assessed the relationship between anthocyanin intake
15 and BP in adults aged 50+y.

16 **Results:** Mean anthocyanins intake was 24.17 ± 0.32 mg/day. Across age-groups, berries were
17 the top sources: blackberry(5-65%); cherry(2-24 %); blueberry(2-13%) and raspberry(3-
18 12%). There was a significant inverse association between anthocyanin intake and systolic
19 BP ($\beta = -0.04$, $F(df)=16.8$ (6), $R\text{-square}=0.05$, $p < 0.01$) and diastolic BP $\beta = 0.01$, $F(df)=5.35$
20 (6), $R\text{-square}=0.013$, $p < 0.01$ ($\beta = -0.01$, $p < 0.01$), in models that adjusted for covariates.

21 **Conclusion:** In comparison to the world composite database, anthocyanin intake in the
22 Australian population was above average (24.17 ± 0.32 mg/day vs 18.05 ± 21.14 mg/d). Berries
23 made up the primary sources thereof. Anthocyanin intake in older adults aged 50+y was
24 inversely associated with blood pressure.

25 **Keywords:** Anthocyanins, dietary intake, food sources, blood pressure, Australia Health
26 Survey

27

28 Introduction

29 Incorporating fruits and vegetables in to the usual human diet has been shown to exert
30 protective effects on health. These observed effects have been attributed to the presence of
31 minerals, vitamins, phytochemicals and dietary fibre in these food groups ⁽¹⁾. Phytochemicals
32 include phenols, terpenes, thiols, phytic acids, phytosterols and protease inhibitors. The
33 phenols are the largest class of phytochemicals ⁽²⁾ and these bioactive compounds,
34 independently and as a group in fruits and vegetables have been associated with reduced
35 mortality ⁽³⁾ weight loss ⁽⁴⁾ cardiovascular diseases ⁽⁵⁾ and some cancers⁽⁶⁾.

36 Anthocyanins are a subgroup of polyaromatic phenols. They are one of the major subgroups.
37 Epidemiological evidence has shown that anthocyanins, aside from being responsible for the
38 deep dark colours in fruits and vegetables, may also exert beneficial effects to health. To date,
39 the most promising protective health effects of anthocyanins appear to be related to blood
40 pressure regulation ^(5, 7, 8), vascular health ⁽⁹⁾, and cognitive function ^(10, 11). Chronic
41 inflammation as a result of raised blood pressure increases the risk of chronic diseases,
42 including stroke, coronary heart disease, chronic kidney disease and heart failure ^(12, 13).

43 Anthocyanins as part of the overall diet plays an integral role in the regulation of chronic
44 inflammation ⁽¹⁴⁾. Fruits such as berries, with high anthocyanin contents, among others have
45 been labelled as anti-inflammatory foods using the Dietary Inflammatory Index (DII) ⁽¹⁵⁾
46 which is a system to assess the quality of foods based on their inflammatory potential ⁽¹⁵⁾

47 Despite emerging evidence regarding the beneficial health effects of anthocyanins, inter-
48 individual variability in their metabolism, which in part may be related to differing
49 microbiota profiles ^(16, 17), has hampered identification of optimal intakes, as well as
50 elucidation of their role in cardio-metabolic health. The food matrix in fruits and vegetables
51 may contribute to the wide inter-individual variability in the metabolism and subsequent
52 effects of anthocyanins. Different cardiovascular and metabolic responses have been shown
53 according to the food source of these compounds ^(18, 19). The synergistic effect of other
54 diverse compounds and nutrients present in the source foods has been explored by others ^{(20,}
55 ²¹⁾.

56 Accurate measurement of nutrient intakes, in this case anthocyanins, tailored specifically to
57 individual countries and regions is an important consideration in both epidemiological and
58 experimental studies ⁽²²⁾. Due to variations in climate, soil conditions and methods of plant
59 harvesting, nutrient levels differ in foods produced across different regions ^(23, 24). This

60 variation in nutrient content has led to the development of country/region specific food
61 composition databases. Currently the United States Department of Agriculture (USDA)
62 Database for the Flavonoid Content of Selected Foods and the European Phenol-Explorer
63 food composition databases exist for the measurement of polyphenol (including anthocyanin)
64 intakes^(25, 26). Comparing these two databases for the estimation of dietary polyphenol intake
65 in Polish adults, Witkowska et al. (2015)⁽²⁷⁾ demonstrated significant discrepancies between
66 the amount of flavonoid intake, estimated at 525 mg/d vs 403.5 mg/d, respectively ($p < 0.001$).
67 This discrepancy led to the first stage development of an Australian anthocyanin database to
68 determine the amount of anthocyanins consumed by Australians⁽²⁸⁾ due to the difference in
69 climate and agricultural practices in this region.

70 Following the development of an Australian anthocyanin database, the primary aim of this
71 study was to use this newly developed anthocyanin database to estimate the intake of both
72 total anthocyanins and their subclasses in a nationally representative sample of the Australian
73 population and compare intakes to the world composite database and other population studies
74⁽²⁹⁾ as well as determine the top food contributors of anthocyanins in Australians.

75 Evidence from blood pressure intervention studies have shown that more significant effects
76 are observed in older adults^(7, 8) and elevated blood pressure as part of metabolic syndrome is
77 common in people aged 50+ years⁽³⁰⁾. A secondary aim of this study was therefore to
78 determine whether there was an association between anthocyanin intakes and blood pressure
79 in Australians aged 50 years and older.

80 **Materials and methods**

81 This study was a secondary data analysis of the 2011–12 National Nutrition and Physical
82 Activity Survey (NNPAS) data from the Australian Bureau of Statistics (ABS) using Basic
83 Confidentialised Unit Record Files. The NNPAS 2011-12 is a component survey of the 2011-
84 13 Australian Health Survey (AHS) which involved a total of 12,153 persons carried out
85 between 29 May 2011 and 9 June 2012 in approximately 9,500 private dwellings selected
86 throughout non-very remote areas of Australia.

87 This survey was conducted using a stratified multistage area sample of private dwellings.
88 Survey aims were designed to provide detailed and broad level estimates for each
89 state/territory and Australia, capital city/balance of state area, regions and sub-populations.

90 Within selected households, a random sub-sample of residents was selected as follows:

91

92 ▪ one adult (aged 18 years and older), and (where applicable)

93 ▪ one child aged 0-17 years (AHS)

94 ▪ one child aged 2-17 years (NNPAS) ⁽³¹⁾.

95 Data collection for NNPAS involved face-to-face interview (and by telephone for the second
96 NNPAS interview) to collect data on general demographic information (including age, sex,
97 marital status and country of birth) for all individuals while detailed information was
98 collected from one adult and one child aged 2-17 years. The survey sampling method
99 covered about 97% of the people and households in Australia from which the study
100 population was sampled.

101 A 24-hour dietary recall method was used to collect information on food, beverages and
102 dietary supplements consumed, as well as some general information on dietary behaviours.

103 All participants (n=12,153) provided the first dietary recall through interviewer-administered
104 format using the Automated Multiple-Pass Method⁽³²⁾ adapted to reflect the Australian food
105 supply ⁽³³⁾. All respondents were invited to take part in a second 24hr dietary recall,
106 conducted using computer assisted telephone interview. Data was collected from 63% of
107 respondents (n=7735). To account for seasonal changes in health and nutritional intake, the
108 NNPAS data collection was randomly spread over a 12-month period. Calculation of the
109 person weights adjusted for this seasonal variation.

110 No ethics approval was required for this study because it was a secondary analysis. However,
111 approval to carry out a secondary analysis with the NNPAS component of the AHS data was
112 obtained by the researchers from the Australian Bureau of Statistics prior to conducting this
113 study.

114 *Estimation of anthocyanin intake*

115 Estimation of anthocyanin intake occurred by applying a newly developed Australian
116 anthocyanin database to the dietary records. The methods of the development of the database,
117 including its strengths and weaknesses, are reported elsewhere ⁽²⁸⁾. Briefly, analytical values
118 were systematically searched, and local researchers were contacted for unpublished data.

119 Following compilation of the data, values were borrowed from the USDA flavonoid database
120 for selected foods as well as the European Phenol-Explorer database. Borrowed values were
121 converted for Australian foods using a moisture conversion factor. There are a total of 5740
122 foods in the Australian Food and Nutrient Database (AUSNUT) 2011-13; of these,
123 anthocyanin values were assigned to 318 individual foods.

124 The AUSNUT 2011–13 is a food composition database of food, dietary supplement and
125 nutrient intake estimates that was compiled from participants' responses to the 2011–12
126 NNPAS. For the current analysis, the NNPAS data was expanded to include anthocyanin
127 content of reported foods and total intakes were calculated based on the amount of food (g)
128 consumed for each day of recall.

129 Using the two separate days of 24hr dietary recall data, usual anthocyanin intake was
130 calculated using the multiple source method (MSM) ^(34, 35). The MSM comprises three steps.
131 First, for each respondent in the study sample, the probability of consumption of the response
132 variable on a randomly selected day was calculated. Secondly, the usual amount of food
133 group intake on reported consumption days was estimated, and finally, the usual overall
134 intakes were calculated by multiplying probability of consumption of the response variable
135 with usual amount of intake on consumption days. Intake values were calculated within the
136 MSM model assuming all participants were habitual consumers, given anthocyanins are
137 primarily found in fruit and vegetables, with age and gender included as covariates. Two
138 variables were produced in the MSM output; usual daily intake of anthocyanins for all
139 participants calculated by the MSM (e.g. measure of habitual intake) and the usual intake of
140 anthocyanins in consumers from the 24-h dietary recall calculated by the MSM. Both of these
141 variables were used in the statistical analysis (**Figure 1**).

142

143 *Statistical Analysis*

144 Statistical analysis was carried out using SAS (release 9.4, 2012; SAS Institute). Daily
145 anthocyanin intake was calculated and expressed as mean and standard error (SE). The total
146 population analysis was based on usual daily anthocyanin intake for all participants and the
147 consumer population analysis was based on the usual intake of anthocyanins in consumers
148 only. Intake of the major sub-classes of anthocyanins (cyanidins, delphinidins, malvidins,
149 pelargonidin, peonidins and petunidins) were also calculated. Weighting factors (person

150 weights and replicate weights produced by ABS ⁽³⁶⁾ were applied to the data in order to
151 generalise results to the total Australian population at the time the survey and to account for
152 sampling discrepancies.

153 Mean anthocyanin intake for the total population and across sub-groups (age-groups, sex,
154 Body Mass Index (BMI,)) level of education, smoking status and level of physical activity)
155 were calculated. Age-groups were categorised according to those used in the National Health
156 and Medical Research Council Nutrient Reference Values (NRVs) for Australia and New
157 Zealand ⁽³⁷⁾. For the purpose of the analysis, categories of BMI, education, smoking and
158 physical activity were grouped according to the ABS classifications with similar classes
159 grouped together (e.g. underweight Class 3, underweight Class 2 and underweight Class 1
160 grouped as ‘underweight’) and individuals aged less than 15y were classified as ‘not
161 applicable’ to maintain the integrity of the weighting factors applied ⁽³¹⁾.

162 Linear regression analysis was used to determine the relationship between anthocyanin intake
163 and blood pressure in adults aged 50+ y (Figure 1), while adjusting for age and gender
164 (model 1) and adjusting for age, gender, BMI, physical activity, smoking status and whether
165 diagnosed with high blood pressure (by a health professional and/or measured BP \geq 140/90
166 mmHg) (model 2). Inclusion criteria for this analysis were: i) adults aged 50 years and above
167 and ii) who had a valid blood pressure measurement

168 Level of significance was set at 0.05 and calculated from t-test for pair-wise comparisons or
169 ANOVA to determine if there are differences in any of the subgroups where appropriate.

170 **Results**

171 Dietary anthocyanin intake from the NNPAS was estimated at 24.17 ± 0.32 mg/d for the total
172 population (n = 12,153) and 37.68mg/d for the consumer population (n = 8,958). Mean
173 intakes for total and subclasses of anthocyanins according to sociodemographic (gender, age-
174 group, level of education) and lifestyle (BMI, smoking status and physical activity) are
175 reported in **Table 1**. There were more adults than children (n = 9,341 vs 2,812) with no
176 statistically significant difference in anthocyanin intake. Respondents who had high physical
177 activity levels consumed more anthocyanins compared to those who had a sedentary lifestyle
178 (30.04mg/d vs 20.42mg/d, <0.001). A similar trend was also observed for respondents with a
179 Bachelor’s degree compared to those with a diploma or lower (29mg/d vs 24mg/d, t-test p-
180 value <0.001).

181 The top ten food sources stratified by age are shown in **Table 2**. Berries are highly
182 concentrated sources of anthocyanins ^(28, 38) and were the top contributors to total anthocyanin
183 intake across all age-groups. The top ten food sources were reported as these made up more
184 than 50% of the total anthocyanin intake across all age-groups.

185 There was a significant inverse association between measured systolic and diastolic blood
186 pressure and anthocyanin intake (**Table 3**). This was evident for both systolic ($\beta = -0.04$, F
187 (df) = 7.77 (2), R square = 0.01, p=0.001) and diastolic ($\beta = -0.01$, F (df) = 5.72 (2), R square
188 = 0.01, p=0.005) blood pressure (Model 1: adjusted for age and gender). After controlling for
189 further confounders (Model 2: age, gender, BMI, physical activity, high BP diagnosis,
190 smoking status and physical activity), the association remained significant ($\beta = -0.04$, F (df) =
191 16.8 (6), R square = 0.05, p<0.01 for systolic BP; and $\beta = 0.01$, F (df) = 5.35 (6), R square =
192 0.013, p<0.01 for diastolic BP).

193 **Discussion**

194 Using nationally representative dietary survey data, this study reports an observed wide
195 distribution of anthocyanin intake in the Australian population. The estimated mean intake
196 was 24.17 ± 0.32 mg/d which is midway between estimates reported for other populations that
197 range between 2.9 and 42.79mg/d (**Table 4**), and was above average in comparison to the
198 world composite database ⁽²⁹⁾. There were variations in anthocyanin intake across subgroups
199 analysed, for example a higher anthocyanin intake in the 51-70y age-group (27.75 ± 0.65
200 mg/d) compared to the lowest consumption (18.56 ± 0.87 mg/d) in the 14-18y age-group
201 (p<0.001). Adults with a post-graduate qualification had higher anthocyanin intakes ($30.09 \pm$
202 1.47 mg/d) compared to those without school qualifications (20.57 ± 0.43 mg/d) (p<0.001)
203 while highly active adults (30.04 ± 1.11 mg/d) had higher intakes compared to sedentary
204 respondents (20.42 ± 0.73 mg/d) (p<0.001). These results are consistent with previous reports
205 on the significant association between socio-demographic and lifestyle factors and fruit and
206 vegetable consumption ⁽³⁹⁻⁴²⁾. Surprisingly, ex-smokers reportedly consumed significantly
207 higher daily anthocyanins (27.68 ± 0.88 mg/d), more than both smokers (18.21 ± 0.68 mg/d)
208 and non-smokers (24.33 ± 0.45 mg/d). Zamora-Ros et al.(2010) ⁽⁴³⁾ similarly reported that
209 ex-smokers consumed more anthocyanins (11.16mg/d) than non-smokers (10.62mg/d).

210 Estimation of anthocyanin intake in the Australian population is an important preliminary
211 step in understanding anthocyanin-health relationships. Despite increased research interest on
212 the observed health benefits of anthocyanins provided by food and beverages, the
213 accompanying increased prevalence of consumption of processed foods translates to a
214 reduced consumption of dietary anthocyanins ⁽⁴⁴⁾. In the 1970s, average daily dietary
215 anthocyanin intake in the USA. was estimated at 215 mg/d in the summer and 180 mg/d
216 during winter ⁽⁴⁵⁾. Current estimates show that dietary anthocyanin intake ranges between 3-
217 43mg/day across countries and tends to be higher in Southern compared to Northern
218 European countries (**Table 4**).

219 Consumption of anthocyanin subclasses were also reported for the total and consumer
220 populations. Cyanidins and malvidins were the most prevalent anthocyanins in both the
221 general and consumer populations and across subgroups. In the 51-70y age-group, malvidins
222 were the most prevalent anthocyanins. This could be explained by the difference in
223 consumption pattern of the major food contributors of anthocyanins in this age-group being
224 red wine, which has a high content of malvidins. A similar trend was also observed in other
225 Australian population studies ^(46,47) with red wine as a major contributor of anthocyanins in
226 older participants.

227 The highest contributing foods (top 10) of dietary anthocyanin in the Australian population
228 were berries, principally blueberries, blackberries, raspberries, and cherries. Berries are
229 known to contain a very high concentration of anthocyanins ⁽⁴⁸⁾. Given this, anthocyanin
230 research has generally focused on berries at the expense of other high anthocyanin foods,
231 such as plums and eggplants which also made up some of the top 10 contributors of
232 anthocyanins in the Australian population. Accordingly, it might be worth further
233 exploration to gather epidemiological evidence of the health-related benefits related to these
234 foods.

235 Results from this study showed a significant association between anthocyanin intake in older
236 adults and lower blood pressure. This result is in agreement with current evidence from
237 clinical and epidemiological studies on the effect of dietary anthocyanins on blood pressure
238 in acute settings and over the longer term ^(7, 8, 49). Anthocyanins have also been classified as
239 nutraceuticals in their ability, as part of a food component, to provide health and medical
240 benefits ⁽⁵⁰⁾. However, it is unlikely that these health benefits are the independent effects of
241 anthocyanins instead a synergistic effect with other polyphenols ⁽⁵¹⁾. This emphasises the

242 importance of studying anthocyanin food sources, consistent with this study, rather than
243 isolated anthocyanins. A review by Pascual-Teresa et al. (2010) ⁽⁵²⁾ observed that evidence
244 related to the protective effects of anthocyanins, as part of the diet, against cardiovascular
245 disease risks has been consistent over the years. Dietary patterns high in fruits and
246 vegetables such as blueberries, apples, and leafy greens that are high in natural antioxidants
247 and polyphenols (anthocyanins) have been shown to reduce the risk of high blood pressure
248 ⁽⁵³⁾ and other chronic diseases evident in the Dietary Inflammatory Index ⁽¹⁴⁾. This evidence
249 has been consistent with similar dietary patterns. Using the Dietary Inflammatory Index,
250 Steck et. al (2014) ⁽⁵⁴⁾ found that the Mediterranean diet showed anti-inflammatory potential
251 based on the resulting DII scores. In addition, the Nordic diet significantly reduced 24-h
252 ambulatory diastolic blood pressure (DBP) and mean arterial pressure in comparison to a
253 control diet based on mean nutrient intakes in Nordic countries ⁽⁵⁵⁾. Other dietary patterns
254 that emphasise high fruit and vegetable intake (the Dietary Approach to Stop Hypertension),
255 low-carbohydrate, Palaeolithic, high-protein, low-glycaemic index, low-sodium, and low-
256 fat diets) were also found to significantly reduce blood pressure (systolic blood pressure
257 (-8.73 to -2.32 mmHg) and DBP (-4.85 to -1.27 mmHg)) in comparison to control/usual
258 diets ⁽⁵⁶⁾. Attributable risk related to the polyphenols present in these diets (i.e. anthocyanins)
259 cannot be disentangled from other health-promoting components of key foods included in
260 these blood pressure lowering dietary patterns.

261 Previous studies have estimated the dietary flavonoid intake in selected Australian
262 populations using weighed food records ⁽⁴⁷⁾ and from National Nutrition Survey (1995) data
263 using a single 24-h dietary recall questionnaire ⁽⁴⁶⁾. Our results using the latest nationally
264 representative survey data differ significantly from earlier studies with higher values reported
265 in the current study. This is possibly due to differences in the method of dietary assessments
266 as well as the use of the MSM to calculate usual daily intake from two repeated 24-h dietary
267 recalls, it could also be as a result of difference/change in population characteristics. Our
268 analysis indicates that the Australian population consume intermediate quantities of
269 anthocyanins compared to other populations (Table 4), but that are similar to estimates from
270 some European countries including Belgium, Norway, Sweden and Denmark ^(57, 58). A need
271 for tailored databases for nutritional epidemiological studies cannot be overemphasised.
272 Following the development of the first Australian food composition database in the mid-
273 1980s, comparative analysis showed that using the UK and US databases overestimated
274 specific nutrient contents by up to 60% ⁽⁵⁹⁾. As a result, it is imperative that databases be

275 tailored to the specific food supply of the population under study. However, development of
276 nutrient databases is fraught with incomplete coverage of all nutrients hence, borrowing and
277 calculating nutrient values is a known validated method in the absence of analytical values
278 ⁽⁶⁰⁾.

279 To our knowledge, this is the first time that dietary anthocyanin intake in the Australian
280 population has been estimated using an Australian-specific anthocyanin database, this being a
281 major methodological strength. Another notable strength is the use of a representative sample
282 of the Australian population, as well as the validated method (MSM) of calculating usual
283 nutrient intake from repeated 24h dietary recalls ⁽³⁴⁾. Some of the limitations of this study
284 include the use of 24-h diet recall questionnaires in the NNPAS (1-2). The single 24-h diet
285 recall has been deemed insufficient because of the retrospective method of dietary assessment
286 and an inability to describe the typical diet from a single day's intake. In addition, the recall
287 is dependent on the memory and cooperation of the participant ⁽⁶¹⁾. Four repeated 24-h diet
288 recalls have been recommended as the most appropriate method for large surveys, ⁽⁶²⁾ while
289 two were applied in the NNPAS. This study applied a regression model to these data to better
290 represent usual intake although no adjustments were made to potential misreporting of the
291 data. A further limitation relates to the effects of processing and storage ⁽⁶³⁾ which was not
292 taken into consideration in the borrowed data used from USDA and Phenol-Explorer food
293 composition databases. Finally, the omission of anthocyanin intake from dietary supplements
294 is a notable limitation of this study. It is however unlikely that such supplements are widely
295 used in Australia, and composition of supplements and extracts in the AUSNUT food
296 composition database did not include polyphenols (anthocyanins). Each of these elements
297 could have led to both over- and underestimation of anthocyanin intake.

298 The cross-sectional nature of this study limits interpretation of the inverse association found
299 between anthocyanin intake and blood pressure. However, evidence is beginning to emerge
300 from experimental studies that support a protective role of anthocyanins on CVD risk in both
301 young and older adults ⁽⁶⁴⁾. For two foods, plum and red cabbage, the Australian analytical
302 data only reported total anthocyanins but not anthocyanin subclasses. Many fruits and
303 vegetables that are high in anthocyanins are seasonal, available only in summer and autumn
304 in Australia, therefore contribution to total intake will depend on the time of year that surveys
305 are conducted. For example, red cabbage is a rich source of anthocyanins but accounted for
306 less than 1% (0.2%) of total anthocyanin intake in the Australian population. This could also
307 be as a result of not many people consuming red cabbage.

308 Although different methods have been described for estimating usual intake, the MSM
309 method involves similar steps to the National Cancer Institute (NCI) method but uses
310 different modelling procedures and handling of non-consumers ⁽⁶⁵⁾. Comparison of the
311 different methods, including those from Iowa State University (ISU), NCI, MSM and
312 Statistical Program to Assess Dietary Exposure (SPADE), showed that with small sample
313 sizes ($n = 150$), the ISU, MSM and SPADE methods were more reliable and showed more
314 precise estimates than the NCI method, mainly for the 10th and 90th percentiles. The
315 observed differences between methods became less significant with larger sample sizes ($n =$
316 300 and $n = 500$) ⁽⁶⁶⁾.

317 **Conclusion**

318 In conclusion, this study estimates for the first time, mean daily intake of anthocyanin in the
319 Australian population, according to sociodemographic characteristics, using an Australian-
320 specific anthocyanin food composition database. Given the rapidly emerging evidence base
321 related to the beneficial effects of anthocyanins on cardiovascular risk factors, it is timeous to
322 assess population-level intake of this flavonoid subgroup. Anthocyanin intake was similar to
323 that reported in southern European countries, and higher than in Northern Europe and USA.
324 Identification of major dietary sources of anthocyanins (blackberry, raspberry, blueberry,
325 cherry, red cabbage, eggplant and red wine) allows for focused dietary messaging.

326

327

328 **Transparency Declaration**

329 The lead author affirms that this manuscript is an honest, accurate, and transparent account of
330 the study being reported. The reporting of this work is compliant with STROBE- nut
331 guidelines. The lead author affirms that no important aspects of the study have been omitted
332 and that any discrepancies from the study as planned have been explained.

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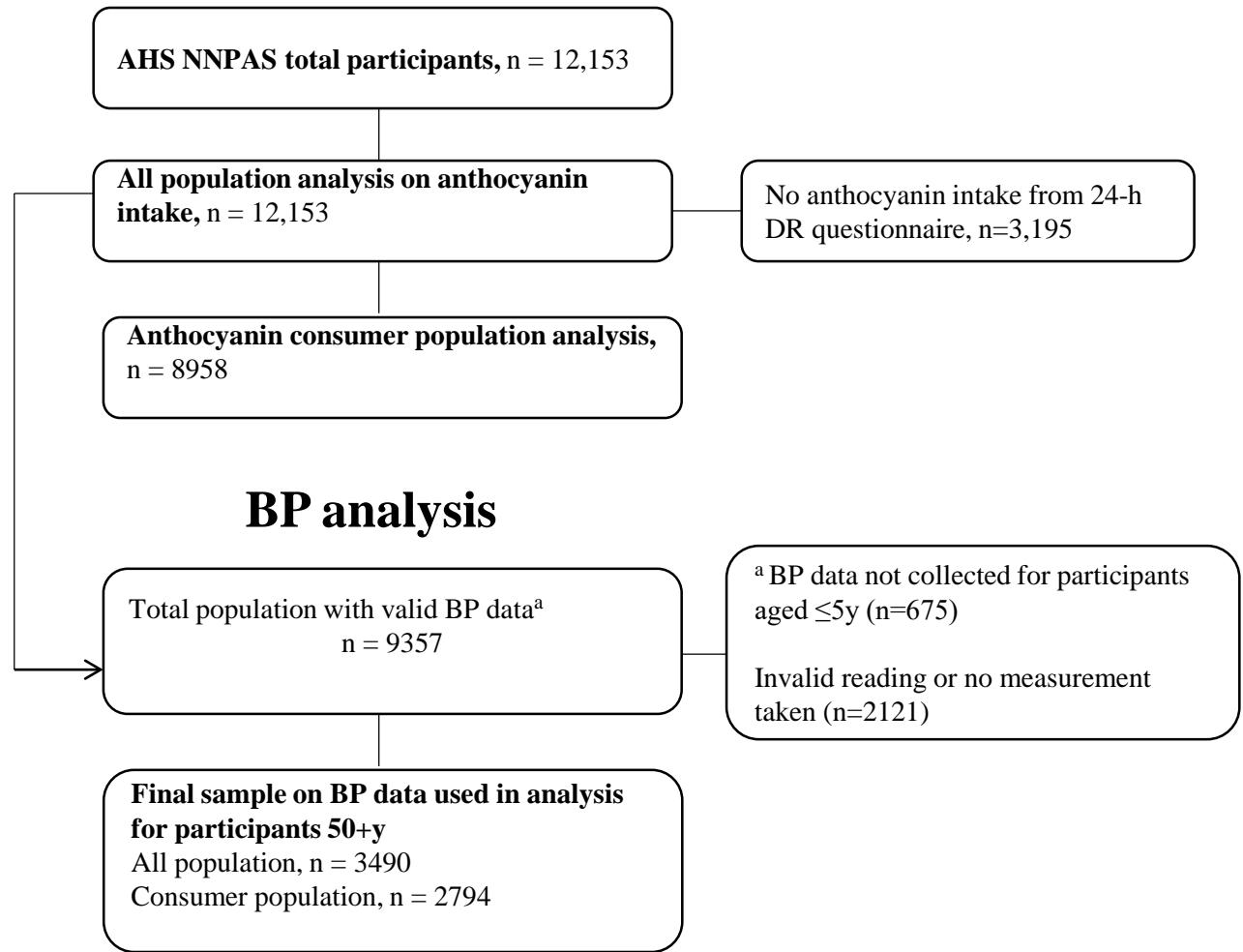


Figure 1: Participant flowchart for secondary analysis of the Australian Health Survey, NNPAS component

Table 1: Anthocyanin intakes by demographic and lifestyle factors for the Australian population (and consumer population) in 2011–12 NNPAS

Stratification variable	N	Anthocyanins(mg/d)			Cyanidins (mg/d)			Delphinidin (mg/d)			Malvidin (mg/d)			Pelargonidin (mg/d)			Peonidin (mg/d)			Petunidin (mg/d)		
		Mean	SE	P	Mean	SE	P	Mean	SE	P	Mean	SE	P	Mean	SE	P	Mean	SE	P	Mean	SE	P
Total NNPAS population (consumer population)	12153 (8958)	24.17 (37.68)	0.32 (0.41)		9.33 (15.22)	0.13 (0.23)		3.03 (5.07)	0.07 (0.12)		7.61 (14.14)	0.20 (0.42)		0.12 (0.21)	0.01 (0.02)		1.12 (1.99)	0.02 (0.05)		1.05 (1.98)	0.04 (0.08)	
Gender				<0.001 (<0.001)			<0.001			<0.001			<0.001			<0.001			<0.001			<0.001
Male	5702 (4030)	23.62 (38.27)	0.41 (0.63)		9.41 (16.04)	0.17 (0.33)		2.83 (4.89)	0.06 (0.11)		7.46 (14.46)	0.29 (0.67)		0.11 (0.21)	0.01 (0.03)		1.08 (1.98)	0.03 (0.07)		1.00 (1.97)	0.04 (0.09)	
Female	6451 (4928)	24.72 (37.14)	0.47 (0.67)		9.27 (14.49)	0.18 (0.29)		3.22 (5.24)	0.13 (0.22)		7.76 (13.85)	0.23 (0.48)		0.13 (0.21)	0.01 (0.02)		1.16 (2.00)	0.04 (0.08)		1.10 (2.00)	0.06 (0.13)	
Age group (yrs.)				<0.001 (<0.001)			<0.001			<0.001			<0.001			<0.001			<0.001			<0.001
Children (≤18)	2812 (2071)	22.46 35.25	0.58 0.90		10.97 (17.96)	0.28 (0.45)		2.51 (4.04)	0.11 (0.18)		4.86 (9.33)	0.33 (0.72)		0.11 (0.20)	0.01 (0.02)		0.89 (1.58)	0.05 (0.09)		0.57 (1.08)	0.07 (0.14)	
2-3	464 (378)	21.51 (31.11)	1.40 (1.86)		7.54 (11.06)	0.43 (0.83)		3.45 (5.59)	0.28 (0.44)		6.34 (11.18)	0.89 (1.53)		0.14 (0.27)	0.02 (0.04)		0.99 (1.67)	0.13 (0.21)		0.83 (1.49)	0.16 (0.27)	
4-8	789 (633)	26.06 (37.04)	1.30 (1.78)		12.31 (18.60)	0.75 (1.17)		3.12 (4.59)	0.34 (0.52)		6.51 (11.55)	0.67 (1.25)		0.16 (0.26)	0.02 (0.03)		1.51 (1.87)	0.11 (0.19)		0.83 (1.40)	0.19 (0.31)	
9-13	787 (576)	22.92 (36.29)	0.91 (1.40)		12.02 (20.01)	0.53 (0.86)		2.11 (3.42)	0.12 (0.21)		4.38 (8.54)	0.49 (1.14)		0.09 (0.16)	0.01 (0.02)		0.83 (1.50)	0.06 (0.11)		0.43 (0.87)	0.06 (0.15)	
14-18	772 (484)	18.56 (33.69)	0.87 (1.74)		9.80 (18.13)	0.51 (1.09)		1.94 (3.29)	0.12 (0.22)		3.06 (6.41)	0.44 (1.22)		0.07 (0.14)	0.01 (0.02)		0.64 (1.25)	0.06 (0.15)		0.36 (0.72)	0.07 (0.18)	
Adults (≥19)	9341 (6887)	24.66 38.38	0.35 0.44		8.87 (14.43)	0.13 (0.23)		3.17 (5.37)	0.07 (0.13)		8.39 (15.52)	0.23 (0.47)		0.12 (0.21)	0.01 (0.02)		1.18 (2.11)	0.03 (0.06)		1.19 (2.24)	0.04 (0.08)	
19-30	1592 (1017)	19.24 (34.24)	0.68 (1.07)		8.48 (15.73)	0.29 (0.60)		2.42 (4.60)	0.13 (0.25)		4.62 (10.08)	0.45 (1.43)		0.16 (0.33)	0.04 (0.09)		0.78 (1.61)	0.05 (0.15)		0.57 (1.29)	0.06 (0.16)	
31-50	3565 (2543)	25.66 (40.55)	0.66 (0.91)		9.58 (15.79)	0.27 (0.45)		3.22 (5.48)	0.14 (0.25)		8.40 (15.84)	0.41 (0.85)		0.11 (0.17)	0.01 (0.01)		1.19 (2.13)	0.05 (0.09)		1.24 (2.35)	0.07 (0.15)	
51-70	2907 (2300)	27.75 (40.20)	0.65 (0.97)		8.88 (13.39)	0.24 (0.42)		3.55 (5.71)	0.13 (0.27)		10.97 (18.96)	0.49 (0.98)		0.11 (0.18)	0.01 (0.02)		1.46 (2.46)	0.06 (0.11)		1.54 (2.75)	0.08 (0.16)	

Stratification variable	N	Anthocyanins(mg/d)			Cyanidins (mg/d)			Delphinidin (mg/d)			Malvidin (mg/d)			Pelargonidin (mg/d)			Peonidin (mg/d)			Petunidin (mg/d)		
		Mean	SE	P	Mean	SE	P	Mean	SE	P	Mean	SE	P	Mean	SE	P	Mean	SE	P	Mean	SE	P
71+	1277 (1027)	24.61 (33.64)	1.15 (1.37)		7.29 (10.80)	0.32 (0.48)		3.64 (5.37)	0.22 (0.33)		9.60 (14.16)	0.61 (0.99)		0.14 (0.23)	0.05 (0.09)		1.27 (1.91)	0.09 (0.16)		1.39 (2.14)	0.15 (0.24)	
BMI (kg/m²)				<0.001 (<0.001)			<0.001			<0.001			<0.001			<0.001			<0.001			<0.001
< 25	4876 (3668)	24.38 (37.76)	0.59 (0.83)		9.91 (16.04)	0.21 (0.39)		3.02 (4.99)	0.14 (0.22)		7.29 (13.73)	0.30 (0.64)		0.14 (0.24)	0.02 (0.03)		1.12 (1.99)	0.04 (0.08)		1.03 (1.96)	0.07 (0.13)	
25 to < 30	3044 (2274)	25.51 (39.10)	0.58 (0.87)		9.21 (14.92)	0.25 (0.41)		3.10 (5.24)	0.09 (0.19)		8.96 (16.70)	0.45 (0.96)		0.12 (0.21)	0.02 (0.04)		1.25 (2.24)	0.05 (0.10)		1.24 (2.36)	0.06 (0.14)	
≥ 30	2258 (1607)	23.23 (37.02)	0.76 (1.06)		8.53 (14.09)	0.30 (0.53)		3.08 (5.34)	0.15 (0.28)		7.36 (13.36)	0.46 (0.99)		0.09 (0.17)	0.02 (0.04)		1.06 (1.91)	0.06 (0.12)		1.00 (1.90)	0.07 (0.18)	
Measurement not taken	1975 (1409)	22.46 (35.68)	0.69 (1.09)		8.96 (14.74)	0.31 (0.56)		2.86 (4.71)	0.13 (0.27)		6.51 (11.67)	0.43 (0.92)		0.09 (0.16)	0.01 (0.01)		0.97 (1.62)	0.05 (0.10)		0.82 (1.47)	0.06 (0.13)	
Level of education				<0.001 (<0.001)			<0.001			<0.001			<0.001			<0.001			<0.001			<0.001
Not applicable	2180 (1676)	23.64 (35.87)	0.70 (1.08)		11.36 (18.06)	0.35 (0.61)		2.65 (4.21)	0.14 (0.22)		5.39 (10.10)	0.38 (0.81)		0.12 (0.22)	0.01 (0.02)		0.96 (1.68)	0.06 (0.11)		0.62 (1.16)	0.09 (0.17)	
Post-Grad	770 (629)	30.09 (44.42)	1.47 (1.92)		10.08 (15.66)	0.57 (0.81)		3.70 (5.88)	0.22 (0.40)		11.46 (20.61)	0.86 (1.68)		0.12 (0.20)	0.02 (0.02)		1.57 (2.69)	0.10 (0.20)		1.71 (3.09)	0.14 (0.28)	
Bachelors	1615 (1304)	29.90 (44.07)	1.22 (1.63)		10.84 (16.84)	0.35 (0.54)		3.75 (6.13)	0.27 (0.46)		10.07 (18.23)	0.65 (1.27)		0.17 (0.32)	0.04 (0.08)		1.46 (2.52)	0.09 (0.17)		1.54 (2.86)	0.13 (0.26)	
Diploma/TAFE Courses	3252 (2341)	24.61 (39.10)	0.56 (0.77)		8.74 (14.39)	0.21 (0.38)		3.07 (5.23)	0.12 (0.19)		8.71 (16.56)	0.35 (0.74)		0.12 (0.19)	0.02 (0.03)		1.22 (2.24)	0.04 (0.10)		1.21 (2.35)	0.06 (0.14)	
No Non-School Qualification	4190 (2893)	20.57 (32.99)	0.43 (0.71)		8.08 (13.54)	0.22 (0.44)		2.72 (4.68)	0.07 (0.17)		6.07 (11.02)	0.25 (0.59)		0.10 (0.18)	0.02 (0.04)		0.89 (1.55)	0.03 (0.06)		0.80 (1.48)	0.04 (0.08)	
Level not determined	146 (115)	29.06 (41.95)	2.40 (3.71)		9.32 (14.21)	1.04 (1.69)		4.43 (7.32)	0.67 (0.35)		10.25 (17.42)	1.60 (3.00)		0.09 (0.15)	0.02 (0.04)		1.35 (2.15)	0.17 (0.31)		1.53 (2.70)	0.27 (0.53)	
Smoking status				<0.001 (<0.001)			<0.001			<0.001			<0.001			<0.01			<0.001			<0.001
Not applicable	2180 (1676)	23.64 (35.87)	0.70 (1.08)		11.36 (18.06)	0.35 (0.61)		2.65 (4.21)	0.14 (0.22)		5.39 (10.10)	0.38 (0.81)		0.12 (0.22)	0.01 (0.02)		0.96 (1.68)	0.06 (0.11)		0.62 (1.16)	0.09 (0.17)	
Smoker	1813	18.21	0.68		7.28	0.34		2.20	0.11		5.27	0.33		0.15	0.05		0.78	0.04		0.73	0.05	

Stratification variable	N	Anthocyanins(mg/d)			Cyanidins (mg/d)			Delphinidin (mg/d)			Malvidin (mg/d)			Pelargonidin (mg/d)			Peonidin (mg/d)			Petunidin (mg/d)		
		Mean	SE	P	Mean	SE	P	Mean	SE	P	Mean	SE	P	Mean	SE	P	Mean	SE	P	Mean	SE	P
	(1073)	(32.61)	(1.10)		(13.38)	(0.68)		(4.14)	(0.25)		(10.52)	(0.87)		(0.26)	(0.11)		(1.43)	(0.10)		(1.47)	(0.13)	
Ex-smoker	3096 (2365)	27.68 (41.65)	0.88 (1.34)		9.40 (14.81)	0.28 (0.45)		3.38 (5.42)	0.12 (0.21)		10.44 (18.77)	0.56 (1.10)		0.11 (0.17)	0.01 (0.01)		1.42 (2.48)	0.07 (0.13)		1.52 (2.82)	0.09 (0.18)	
Never smoked	5064 (3844)	24.33 (37.41)	0.45 (0.70)		9.18 (14.79)	0.20 (0.33)		3.24 (5.46)	0.11 (0.20)		7.65 (14.01)	0.27 (0.58)		0.12 (0.22)	0.01 (0.03)		1.12 (1.97)	0.03 (0.07)		1.06 (1.96)	0.05 (0.10)	
Physical activity				<0.001 (<0.001)			<0.001			<0.001			<0.001		ns				<0.001			<0.001
Not applicable	2718 (2010)	22.64 (35.28)	0.60 (0.93)		10.99 (17.91)	0.28 (0.48)		2.54 (4.09)	0.11 (0.19)		4.98 (9.53)	0.35 (0.75)		0.11 (0.20)	0.01 (0.02)		0.90 (1.60)	0.05 (0.10)		0.57 (1.09)	0.08 (0.15)	
High	1328 (1066)	30.04 (43.83)	1.11 (1.24)		11.34 (17.63)	0.48 (0.67)		3.92 (6.33)	0.35 (0.53)		9.58 (17.28)	0.72 (1.26)		0.11 (0.20)	0.01 (0.02)		1.45 (2.49)	0.09 (0.17)		1.47 (2.73)	0.14 (0.24)	
Moderate	2574 (1950)	25.99 (39.50)	0.69 (0.96)		9.17 (14.55)	0.28 (0.43)		3.32 (5.53)	0.10 (0.20)		9.33 (17.07)	0.40 (0.83)		0.13 (0.21)	0.02 (0.04)		1.31 (2.30)	0.05 (0.10)		1.39 (2.62)	0.07 (0.15)	
Low	3351 (2461)	23.57 (37.13)	0.57 (0.83)		8.44 (13.92)	0.20 (0.37)		2.99 (5.06)	0.10 (0.19)		8.12 (15.05)	0.38 (0.78)		0.10 (0.19)	0.01 (0.03)		1.13 (2.01)	0.05 (0.09)		1.08 (2.01)	0.06 (0.12)	
Sedentary	2075 (1398)	20.42 (34.05)	0.73 (1.27)		7.40 (12.56)	0.27 (0.49)		2.68 (4.74)	0.15 (0.31)		6.44 (12.04)	0.45 (1.04)		0.15 (0.25)	0.04 (0.08)		0.90 (1.63)	0.05 (0.13)		0.86 (1.62)	0.07 (0.17)	
Not stated	107 (73)	26.59 (39.30)	4.93 (6.77)		12.55 (19.03)	3.28 (5.12)		3.28 (4.86)	0.67 (1.15)		7.15 (11.82)	1.54 (3.13)		0.21 (0.37)	0.12 (0.23)		0.99 (1.57)	0.17 (0.32)		1.00 (1.78)	0.22 (0.45)	

p values significant at <0.05 using ANOVA

Table 2: Top ten food sources of anthocyanins in the diet of the Australian population by age-group

		% total anthocyanin intake per age group															
Age (years)		2-3	4-8	9-13	14-18	19-30	31-50	51-70	71+								
n		464	789 ¹	787	772 ²	1592	3565	2907	1277								
1.	Blackberry, raw	36.6	Blackberry, raw	65.2	Blackberry, raw	37.5	Cherry, raw	23.9	Grape, raw, ³	15.4	Eggplant, ⁴	8.1	Eggplant, ⁴	23.1	Eggplant, ⁴	26.4	
2.	Raspberry, raw	12.8	Blueberry, raw	8.3	Blueberry, raw	12.7	Eggplant, ⁴	15.7	Cherry, raw	8.5	Blackberry, raw	7.4	Grape, raw, ³	9.1	Wine, red,	10.3	
3.	Blueberry, raw	10.3	Grape, raw ³	4.9	Grape, raw ³	11.2	Grape, raw ³	14.9	Cranberry, raw	8.2	Cherry, raw	5.7	Blackberry, raw	8.4	Cherry, raw	8.3	
4.	Grape, raw ³	8.6	Cherry, raw	2.6	Cherry, raw	7.3	Raspberry, purchased frozen	8.9	Eggplant, ⁴	5.3	Blueberry, raw	5.1	Wine, red	7.8	Blueberry, raw	7.1	
5.	Cabbage, red, raw	8.8	Raspberry, purchased frozen	2.4	Eggplant ⁴	7.0	Blueberry, raw	8.5	Plum, unpeeled, raw	4.9	Raspberry, raw	4.9	Blueberry, raw	7.1	Blackberry, raw	5.1	
6.	Cherry, raw	4.0	Plum, unpeeled, raw	2.4	Plum, unpeeled, raw	4.8	Cabbage, red, raw	5.9	Bean, black, ⁵	4.5	Cranberry, raw	4.8	Cherry, raw	6.3	Plum, unpeeled, raw	4.9	
7.	Raspberry, purchased frozen	3.4	Blueberry, purchased frozen	2.1	Raspberry, raw	3.2	Plum, unpeeled, raw	5.4	Raspberry, purchased frozen	3.9	Grape, black sultana, raw	4.6	Plum, unpeeled, raw	4.7	Raspberry, purchased frozen	4.7	
8.	Plum, unpeeled, raw	3.2	Eggplant ⁴	2.0	Raspberry, purchased frozen	2.6	Blueberry, purchased frozen	2.0	Blueberry, raw	3.8	Radish, peeled or unpeeled, raw	4.4	Raspberry, raw	2.9	Grape, Thompson,	3.4	
9.	Eggplant ⁴	2.7	Raspberry, raw	1.3	Apple, red skin, unpeeled, raw	1.6	Apple, red skin, unpeeled, raw	1.7	Wine, red	3.8	Raspberry, purchased frozen	4.3	Blueberry, purchased frozen	2.6	Radish, raw	3.2	
10	Blueberry, purchased frozen	1.4	Apple, pink lady, unpeeled, raw	0.9	Pear, unpeeled, raw, not further defined	1.3	Pear, unpeeled, raw, not further defined	1.5	Raspberry, raw	3.2	Wine, red, sparkling	4.1	Cabbage, red, raw	2.4	Raspberry, raw	2.9	
Sum		91.8	92.1	89.2	88.5	61.6	53.5	74.4	76.3								

¹n=2 excluded due to implausible dietary consumption data, ²n=1 excluded due to implausible dietary consumption data, ³Combination of Grape, raw, Grape, red, raw, and Grape, Thompson, seedless;

⁴Eggplant, peeled or unpeeled, fresh or frozen, raw; ⁵Bean, black, dried, boiled, microwaved or steamed, drained

Table 3: Association between anthocyanin intake and change in blood pressure in adults aged 50+yrs

BP parameters	Anthocyanin intake in all population (consumer population) Effect size (regression coefficient and 95% Confidence Interval) per unit (mg) increase					
	Model 1 ¹ n=4184 (3327)			Model 2 ² n=4184 (3327)		
	Regression coefficient	95% CI	p value	Regression coefficient	95% CI	p value
Systolic BP	-0.04 (-0.03)	-0.06, -0.01 (-0.05, -0.01)	0.001* (0.002)*	-0.04 (-0.03)	-0.06, -0.01 (-0.05, -0.01)	<0.01* (<0.01)*
Gender	-2.50 (-2.51)	-4.28, -0.72 (-4.45, -0.58)	0.01 (0.01)	-2.67 (-2.68)	-4.40, -0.94 (-4.62, -0.74)	0.003* (0.01)*
BMI				0.06 (0.1)	-0.002, 0.12 (-0.004, 0.1)	0.06 (0.07)
High BP diagnosis				-7.92 (-7.38)	-9.80, -6.05 (-9.63, -5.12)	<0.001* (<0.001)*
Smoking status				0.70 (1.06)	-0.06, 1.46 (0.11, 2.01)	0.07 (0.03)*
Physical activity				0.09 (0.15)	-0.61, 0.78 (-0.63, 0.92)	0.80 (0.7)
Diastolic BP	0.01 (0.01)	-0.01, 0.02 (-0.01, 0.02)	0.005* (0.03)	0.01 (0.01)	-0.01, 0.03 (-0.01, 0.02)	<0.01* (0.02)*
Gender	-1.56 (-1.31)	-2.51, -0.62 (-2.40, -0.22)	0.002 (0.02)	-1.52 (-1.30)	-2.49, -0.54 (-2.42, -0.18)	0.002* (0.02)*
BMI				0.06 (0.06)	0.03, 0.09 (0.02, 0.11)	<0.001* (0.01)*
High BP diagnosis				-0.77 (-0.54)	-1.76, 0.22 (-1.64, 0.55)	0.12 (0.33)
Smoking status				-0.24 (-0.19)	-0.64, 0.16 (-0.68, 0.30)	0.24 (0.44)
Physical activity				-0.09 (-0.04)	-0.53, 0.35 (-0.49, 0.42)	0.68 (0.88)

¹Model 1 covariates = age (included as a class variable) and gender; ²Model 2 covariates = age (included as a class variable), gender, BMI, hypertension diagnosis, Physical activity and smoking status; * Significant at p<0.05; values in bracket represent analysis for consumer population.

Table 4: Reported anthocyanin intake (mg/d) in population studies by country

Country (reference)	Sample size	Age/Gender ¹	Dietary assessment	Total anthocyanin intake (mg/d)
Australia (this study)	12,153	≥2yrs	2 x 24h DR (MSM method)	24.17
Australia ⁽⁴⁶⁾	10,851	≥2yrs.	24h DR	1.4
Australia ⁽⁴⁷⁾	79	≥49yrs	4-day WFR	7.0
China ⁽⁶²⁾	1393	35-75	FFQ	28 ²
Europe ⁽⁵⁵⁾		35-74yrs.	FFQ (GA ² LEN)	
Denmark	268			7.5
Finland	122			5.9
Sweden	1,085			6.5
UK	139			9.8
Portugal	233			22.1
Belgium	107			10.5
Germany	305			5.5
The Netherlands	174			8.1
Amsterdam				
Poland	116			9.2
Europe ⁽⁵⁶⁾		35-74yrs.	24h DR	
Greece	2,687			31.82
Spain	3,220			31.58
Italy	3,953	35-74yrs./F (1 out of 5 centres)		42.79
France	4,735			37.42
Germany	4,415	35-74yrs./F		35.09
The Netherlands	3,980			22.56
UK	1,280	35-74yrs./F (1 out of 2 centres)		26.12
Denmark	3,917			28.21
Sweden	6,050			20.96
Norway	1,797	35-74yrs./F		26.56
Finland ⁽⁶³⁾	1950	42-60yrs./M	4-day food record	6.2
Finland ⁽⁶⁴⁾	2007	25-64yrs.	48h diet recall	47
France ⁽⁶⁵⁾	4942	45-60yrs.	≥6 24h diet recall	35
Spain ⁽⁴³⁾	40,683	35-64yrs.	Diet history questionnaire	18.88
United Kingdom ⁽⁶⁶⁾	1,997	18-76yrs./F	FFQ	18
USA ⁽⁶⁷⁾	8,809	>19yrs.	24h diet recall	3.1
USA ⁽⁶⁸⁾	5,420	≥20	24h diet recall	11.48

¹ gender specified when sample size is gender specific; WFR, weighted food record; 24hrDR, 24hr dietary recall; ²excludes malvidin and petunidin