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**Tree nut snack consumption is associated with better diet  
quality and cardiovascular disease risk in the UK adult  
population: National Diet and Nutrition Survey (NDNS)  
2008-2014.**

Journal:	<i>Public Health Nutrition</i>
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Manuscript Type:	Research Article
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Subject Category:	6. Nutritional epidemiology

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**1 Abbreviation**

2		
3	ANCOVA	Analysis of covariance
4	BMI	Body Mass Index
5	COMA	Committee on Medical Aspects of Food Policy
6	CRP	C-reactive protein
7	CVD	Cardiovascular disease
8	DBP	Diastolic blood pressure
9	DRV	Dietary Reference Value
10	EAR	Estimated Average Reference
11	ECI	Eating Choice Index
12	<b>GLM</b>	<b>Generalised linear model</b>
13	HDL-C	High density lipoprotein
14	HDS	Healthy diet score
15	IQR	Interquartile range
16	LDL-C	Low density lipoprotein
17	MDS	Mediterranean Diet Score
18	MUFA	Monounsaturated fatty acids
19	NDNS	National Diet and Nutrition Survey
20	NDNS-RP	National Diet and Nutrition Survey - Rolling Programme
21	NHANES	National Health and Nutrition Examination Survey
22	PUFA	Polyunsaturated fatty acids
23	RNI	Reference Nutrition Intake
24	SBP	Systolic blood pressure
25	SD	Standard deviation
26	SFA	Saturated fats
27	SI	Safe Intake
28	TAG	Triglycerides
29	TC	Total cholesterol
30	TNS	Tree nut snacks
31	TNS-A	Any amount of tree nut snacks
32	TNS-B	≥7.08 g tree nut snacks (equivalent to ¼ oz)
33	WC	Waist circumference

34 **Abstract**

35

36 **Objectives:** To examine associations of tree nut snack (TNS) consumption with diet quality and  
37 cardiovascular disease (CVD) risk in UK adults from National Diet and Nutrition Survey (NDNS)  
38 2008-2014.

39 **Design:** Cross-sectional analysis using data from 4-d food diaries, blood samples and physical  
40 measurements for CVD risk markers. To estimate diet quality, modified Mediterranean Diet Score  
41 (MDS) and modified Healthy Diet Score (HDS) were applied. Associations of TNS consumption  
42 with diet quality and markers of CVD risk were investigated using **survey-adjusted** multivariable  
43 linear regression adjusted for sex, age, ethnicity, socio-economic and smoking status, region of  
44 residency and total energy and alcohol intake.

45 **Setting:** UK free-living population.

46 **Subjects:** 4,738 adults ( $\geq 19$ y).

47 **Results:** TNS consumers had higher modified MDS and HDS relative to non-consumers. TNS  
48 consumers also had lower BMI, WC, SBP and DBP and **higher HDL** compared to non-consumers,  
49 although a dose-related fully adjusted significant association between increasing nut intake (g per  
50 1000 kcal energy intake) and lower marker of CVD risk was only observed for SBP. TNS  
51 consumption was also associated with higher intake of total fat, mono-, n-3 and n-6 polyunsaturated  
52 fatty acids, fibre, vitamin A, thiamin, folate, vitamin C, vitamin E, potassium, magnesium,  
53 phosphorus, selenium and iron; and lower intake of **saturated fatty acids**, *trans* fatty acids, total  
54 carbohydrate, starch, free sugar, sodium and chloride.

55 **Conclusions:** TNS consumers report better dietary quality and consumption was associated with  
56 lower CVD risk factors. Encouraging replacement of less healthy snacks with TNS should be  
57 encouraged as part of general dietary guidelines.

58

59 **Keywords:** nuts, cross-sectional analysis, diet quality, cardiovascular disease, nutrients

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## 75 1. Introduction

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77 An average of 2.55 snacks per day are consumed in the UK and Ireland, with over a third of  
78 these snacks being confectionary or crisps/popcorn/nuts<sup>(1)</sup>. Nuts are a popular snack as shown by  
79 the growing trend for consuming tree nuts over the past ten years<sup>(2)</sup>. North America was the region  
80 with the highest production; however, it was Europe that was the largest consumer in the world.  
81 Almonds (*Prunusdulcis*), walnuts (*Juglansregia*), pecans (*Caryaillinoensis*), pine nuts  
82 (*Pinuspinea*), cashews (*Anacardiumoccidentale*), macadamia nuts (*Macadamia*), hazelnuts  
83 (*Corylusavelana*), pistachios (*Pistaciavera*), Brazil nuts (*Bertholletiaexcelsa*) and chestnuts  
84 (*Castanea*) are examples of edible tree nuts that are produced commercially<sup>(2)</sup>.

85

86 Almonds, walnuts, pecans, pine nuts, cashews, macadamia nuts, hazelnuts, pistachios and  
87 Brazil nuts differ to some extent in their nutrient profiles. However, tree nuts are generally energy-  
88 dense, with a high proportion of fat made up of unsaturated fatty acids; low in sodium; and rich in  
89 plant-based protein, dietary fibre, and micronutrients, including niacin, vitamin B6, vitamin E,  
90 vitamin K, folic acid, calcium, magnesium, potassium, selenium, phosphorus and zinc. Tree nuts  
91 are also rich in phytosterols and (poly)phenols, which promote antioxidant and anti-inflammatory  
92 pathways<sup>(3-5)</sup>. Because of these properties, tree nuts and health outcomes have been the focus of  
93 many human clinical trials and observational studies.

94

95 Previous dietary intervention studies showed that tree nut consumption resulted in lowered  
96 type-2 diabetes and cardiovascular disease risk factors. Walnut, almond, pistachio, macadamia,  
97 cashew and hazelnut consumption favourably modified blood lipid profile<sup>(6-15)</sup>, mixed nuts  
98 improved insulin sensitivity<sup>(14)</sup>, and walnuts lowered inflammatory markers<sup>(16)</sup> and improved  
99 endothelium-dependent vasodilation<sup>(17)</sup>, all of which would be predicted to reduce the risk of CVD.  
100 Furthermore, contrary to popular perception, nut-enriched diets are not linked with increased risk of  
101 weight gain<sup>(18)</sup> and tree nut consumption has been shown to assist weight loss as part of an energy-  
102 restricted diet in obese or overweight subjects<sup>(19)</sup>.

103

104 Cross-sectional analysis of tree nut consumption and indicators of diet quality and  
105 cardiovascular health have also been undertaken. In the US adult population ( $\geq 19$  y), using the  
106 National Health and Nutrition Examination Survey (NHANES) 2005-2010 database (n=14,386)  
107 based on 24-h dietary recalls, it was reported that tree nut consumption was linked to lower body  
108 mass index (BMI), waist circumference (WC), systolic blood pressure (SBP), and insulin resistance  
109 index (HOMA-IR) and higher high-density lipoprotein (HDL-C) adjusted for age, sex, ethnicity,  
110 poverty index ratio, physical activity level, smoking status and alcohol intake<sup>(20)</sup>. O'Neil *et al.*  
(2015) also showed that tree nut consumers, compared to non-consumers, had significantly higher  
diet quality scores (HEI-2005, a diet quality score widely used in the USA) and greater nutrient

110 adequacy for dietary fibre, vitamin A, vitamin E, vitamin C, folate, calcium, iron, magnesium, zinc  
111 and potassium<sup>(21)</sup>.

112 The purpose of the present study was to examine associations between tree nut snack (TNS)  
113 consumption and diet quality, dietary patterns, as well as CVD risk markers, in a nationally  
114 representative UK adult population, using data from the UK National Diet and Nutrition Survey  
115 (NDNS) rolling programme 2008-2014. Dietary data were derived from estimated 4-d food diaries  
116 in a population of 4,738 adults ( $\geq 19$ y)<sup>(22,23)</sup>, which differs from the NHANES analysis 2005-2010,  
117 which was based on two multiple pass 24-h dietary recalls in a larger population of 14,386  
118 adults<sup>(21)</sup>. The hypothesis of this study was that greater tree nut snack (TNS) consumption would be  
119 associated with higher diet quality, healthier dietary patterns, greater nutrient adequacy, and lower  
120 prevalence of CVD risk markers in UK adults.

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122

## 123 2. Materials and Methods

124

### 125 2.1. The National Diet and Nutrition Survey Rolling Programme (NDNS-RP) and study population

126

127 The NDNS-RP is a long-running government-funded scheme to assess diet, nutrient intake and  
128 nutritional status of the general population ( $>1.5$ y) living in private households in the UK (England,  
129 Scotland, Wales and North Ireland)<sup>(22,23)</sup>. Random sampling was carried out on addresses  
130 throughout the UK. A single address could have multiple households and a household in an address  
131 was selected randomly. An adult in the household was also randomly selected. Selected participants  
132 were requested to complete a 4-d estimated food diary, interviewed to collect information, such as  
133 dietary habits, socio-demographic background and lifestyle as well as anthropometrically measured  
134 and blood sample taken<sup>(22,23)</sup>.

135 The survey involves two stages: 1) interview visits to collect information on socio-  
136 demography, administer the 4-d food diaries, and carry out anthropometric measurements, and 2) a  
137 nurse visit to do further physical measurements and collect blood and 24-h urine samples<sup>(22,23)</sup>.

138 Following venepuncture, an EDTA and a serum gel monovette tube from each participant's sample  
139 set were sent by post, to the Immunology and Biochemistry Laboratory at Addenbrooke's Hospital  
140 in Cambridge for prompt analysis. The remaining samples (lithium heparin, serum or fluoride blood  
141 monovette tubes) were processed and stored below  $-40^{\circ}$  C (or at a maximum of  $-20^{\circ}$  C where  $-40^{\circ}$  C  
142 facilities were not available), before being transported on dry ice to the Human Nutrition Research  
143 (HNR) facility for analysis. The cross-sectional analysis reported here included data from adult

144 participants ( $\geq 19$  y,  $n=4,738$ ), who completed a 4-d estimated food diary in the NDNS-RP 2008-  
145 2014 (Year 1-6)<sup>(22,23)</sup>.

146

## 147 2.2. Cardiovascular disease risk markers

148

149 Body mass index (BMI;  $\text{kg/m}^2$ ), waist circumference (WC; cm), systolic blood pressure (SBP;  
150 mmHg), diastolic blood pressure (DBP; mmHg), total cholesterol (TC; mmol/l), triglycerides  
151 (TAG; mmol/l), high density lipoprotein (HDL-C; mmol/l), low density lipoprotein (LDL-C;  
152 mmol/l), TC:HDL-C (the ratio of TC and HDL-C) and C-reactive protein (CRP; mg/l) were CVD  
153 risk markers included in the analysis. Interviewer measurement protocols and procedures for blood  
154 sample collection, processing, analysis and quality controls are detailed elsewhere<sup>(22,23)</sup>. **Body  
155 height and weight were measured using a portable stadiometer and a weight scale, and BMI was  
156 calculated by fieldworkers. Waist circumference measurement was taken using a tape measure. The  
157 discrepancy tolerances of repeat measurement readings were not detailed in the NDNS method  
158 protocols. Omron HEM907, an automated validated monitor, was used to measure blood pressure in  
159 a sitting position after a five-minute rest. Trained fieldworkers took blood pressure measurements  
160 three times and results were presented based on the mean value of second and third readings with  
161 one-minute intervals<sup>(22,23)</sup>.**

162

## 163 2.3. Diet quality indices

164

165 To estimate diet quality, two existing diet scores were used: the Mediterranean Diet Score  
166 (MDS)<sup>(24)</sup> and Healthy Diet Score (HDS)<sup>(25)</sup>. Maynard *et al.* (2004) developed HDS based on  
167 Healthy Diet Indicator (HDI) and the UK guidelines at that point in time, as recommended by the  
168 Committee on Medical Aspects of Food Policy (COMA)<sup>(25)</sup>. Modifications were applied to HDS for  
169 this study to reflect UK current recommendations<sup>(22,26-30)</sup>, and nuts were removed from the MDS  
170 scoring system as appropriate for this study on diet and health associations with nut consumption.  
171 The potential top score of the modified MDS remained the same: 9, but the modified HDS had a  
172 potential top score of 14 while the original HDS scoring range was 0-12 (see Table A2 in  
173 Appendices). Table A1 and A2 in Appendices show original and modified items of MDS and HDS  
174 items respectively.

175

## 176 2.4. Statistical analysis

177

178 Prior to statistical analysis, TNS intake was defined and determined. TNS consumption was  
179 defined as: 1) any amount of consumption, or 2)  $\geq 7.08$  g ( $\frac{1}{4}$  oz) of TNS. The  $\geq 7.08$  g ( $\frac{1}{4}$  oz) cut-off  
180 was adopted to facilitate comparisons with previous cross-sectional analysis of associations  
181 between tree nut consumption and dietary scores/nutrient adequacy in a US adult population<sup>(21)</sup>.  
182 Data on tree nut snack consumption were isolated from the database prior to statistical analysis and  
183 total tree nut snack intakes calculated. Tree nuts included were almonds, walnuts, pecans, pine nuts,  
184 cashews, macadamia nuts, hazelnuts, pistachios, Brazil nuts and chestnuts. Although the US Food  
185 and Drug Administration recognizes coconuts as a tree nut, they were excluded since they are fruits  
186 of palm trees and not commonly consumed whole as a snack food. Peanuts were also excluded  
187 since they are classified as legumes.

188 Statistical analysis was carried out using SPSS IBM 23 and a two-sided *P*-value of 0.05 was  
189 considered statistically significant. Data are presented as adjusted means (95% CI) for individual  
190 nutrient intakes, total diet quality scores as well as levels of CVD risk markers, and as medians  
191 (with IQRs) for the amount of TNS consumed and age. To examine whether there was a statistically  
192 significant association between tree nut consumption and alcohol and total energy intakes as well as  
193 demographic variables, i.e. age, sex, ethnicity, socio-economic and smoking status and region of  
194 residency, survey-adjusted GLM with a binary logistic link function was used. Survey-adjusted  
195 GLM with a linear link function (predictors: age, sex, ethnicity, socio-economic and smoking  
196 status, region of residency, total energy and alcohol intake) was used to examine whether there were  
197 significant differences between TNS consumers and non-consumers in their diet quality scores,  
198 nutrient intakes and CVD risk markers. To investigate dose-response associations between TNS  
199 consumption (g/1000 kcal energy intake) and diet quality and CVD risk markers, survey-adjusted  
200 multivariable linear regression models were used adjusting for the same covariates mentioned  
201 above. Normal residual distributions were checked by visual inspection of Q-Q plots; data with  
202 non-normally distributed residuals were log transformed using  $\log_{10}$  for analysis of survey-adjusted  
203 generalised linear model (GLM) and multivariable linear regression. The results of analysis were  
204 back transformed into the geometric mean values. Homoscedasticity was checked by plotting the  
205 standardised residuals of dependent variables and predictors.

206 During the analysis, the weight factor provided by the NDNS database resource was applied to  
207 adjust for non-response and known socio-economic differences in the survey to ensure that the data  
208 was nationally representative for the UK population and reducing selection bias and non-response  
209 bias<sup>(31,32)</sup>. The weight factor used are wti\_Y14 (Weight for individual and diary-all ages, combined  
210 Y1-4) and wti\_Y56 (Weight for individual and diary-all ages, combined Y5-6) for investigating  
211 differences in diet quality scores and nutrient intakes between TNS consumers and non-consumers,



212 associations between tree nut consumption and demographic variables, and multivariable linear  
213 regression including diet quality scores. Weight factors wtn\_Y14 (Weight for nurse-all ages,  
214 combined Y1-4) and wtn\_Y56 (Weight for nurse-all ages, combined Y5-6) were used for GLM and  
215 multivariable linear regression including variables BMI, waist circumference and blood pressure;  
216 and wtb\_Y14 (Weight for blood-all ages, combined Y1-4) and wtb\_Y56 (Weight for blood-all ages,  
217 combined Y5-6) were used for GLM and multivariable linear regression for blood analyte variables  
218 including C-reactive protein and lipids<sup>(31,32)</sup>.

219

### 220 3. Results

221

#### 222 3.1. Demographic information

223

224 Table 1 shows background characteristics of TNS consumers and non-consumers. Median  
225 TNS-A (any amount of TNS intake) consumption (n = 484) contributed 0.8% of total energy intake  
226 while median consumption in the TNS-B group (including individuals who consumed  $\geq 7.08$  g TNS  
227 per day, equivalent to  $\frac{1}{4}$  oz, n = 224) was 2.3% of total energy intake. On average TNS consumers  
228 were significantly older than non-consumers and were more likely to be female and non-smokers.  
229 TNS-A consumption was significantly associated with the demographic factors included, such as  
230 sex, ethnicity, socio-economic status, smoking status and region of residency. TNS-B consumption  
231 was also significantly associated with these demographic variables, except region of residency.

232

#### 233 3.2. Diet quality scores

234

235 Geometric estimated marginal mean total scores of modified MDS were significantly higher in  
236 TNS-A consumers (5.9; 95% CI 5.2, 6.6) compared with non-consumers (4.9; 95% CI 4.4, 5.4;  
237  $P < 0.001$ ). Similarly, geometric estimated marginal mean total scores for the modified HDS were  
238 significantly higher in TNS-A consumers (6.1; 95% CI 5.5, 6.8) compared with non-consumers  
239 (5.4; 95% CI 4.9, 6.0;  $P < 0.001$ ). Results for TNS-B consumers were almost identical (data not  
240 shown). To investigate dose-response associations between every gram increase in TNS  
241 consumption per 1000 kcal of adult's energy intake and diet quality scores, the survey-adjusted  
242 regression model was adjusted for age, sex, ethnicity, socio-economic and smoking status, alcohol  
243 and energy intakes. There was no dose response observed in the scores of modified MDS and  
244 modified HDS ( $P = 0.726$  and  $P = 0.971$  respectively).

245

#### 246 3.3. Nutrient intake

247

248 TNS consumers had significantly higher total energy, food energy, fat, cis-monounsaturated  
249 fatty acids, cis n-6 fatty acids, cis n-3 fatty acids (TNS-A only), intrinsic milk sugars, and fibre  
250 intakes, as shown in **Table 2**. Saturated fatty acids, trans-fatty acids, total carbohydrate, starch, non-  
251 milk extrinsic sugars, intrinsic milk sugar and starch, and alcohol (TNS-B only) intakes were  
252 significantly lower in TNS consumers. For micronutrients, as shown in **Table 2**, fully adjusted  
253 analysis revealed that TNS consumers, relative to non-consumers, had significantly higher intakes  
254 of vitamin A (TNS-A only), vitamin E, thiamin, riboflavin (TNS-B only), folate, pantothenic acid,  
255 biotin, vitamin C, potassium, magnesium, phosphorus, iron, copper, zinc, manganese and selenium,  
256 and lower intakes of sodium and chloride. However, there were no differences between groups for  
257 vitamins D, riboflavin (TNS-A only), niacin equivalents, vitamin B6, vitamin B12, calcium and  
258 iodine.

259

### 260 3.4. Cardiovascular disease risk markers

261

262 Blood samples were not available from all participants, and anthropometric and blood pressure  
263 data were also missing. Associations between TNS consumption and CVD risk markers were  
264 analysed for the remaining participants. The estimated marginal mean (95% CI) values of CVD risk  
265 markers are shown in **Table 3**. For TNS-A consumers, BMI, WC, SBP and DBP were significantly  
266 lower and HDL was significantly higher compared to non-consumers. For those consuming >7.08 g  
267 TNS/d (TNS-B), only WC, SBP and DBP were significantly lower compared to non-consumers  
268 (data shown in Supplementary document). Survey-adjusted regression analysis showed that for  
269 every gram increase in TNS consumption per 1000 kcal of adults' energy intake (**Table 3**), SBP  
270 was significantly lower demonstrating a dose-response relationship ( $P = 0.028$ ).

271

## 272 4. Discussion

273

274 Interventional and observational evidence suggests that replacing refined carbohydrate-based  
275 snacks with tree nut snacks may improve blood lipid profiles, management of body weight<sup>(33,34)</sup>,  
276 and nutrient intakes. However, TNS intakes in the general UK population have not been fully  
277 investigated. Previous studies have been conducted in the NHANES US adult population<sup>(20,21)</sup> using  
278 multiple 24-h dietary recalls to collect food intake data. This cross-sectional analysis using a  
279 representative UK adult population revealed that just 10% of respondents reported consuming any  
280 amount of TNS during their 4-day food intake recording period, just less than 5% reported  
281 consuming more than 7.08 g (¼ oz) per day on average (around a handful over the 4-day period),

282 and only 0.34% reported consuming the US Food and Drug Administration recommendation of  
283 42.5 g per day<sup>(35)</sup>. The relatively small sub-population of TNS consumers was more likely to be  
284 female, white, older and living in England and less likely to be current smokers relative to non-  
285 consumers.

286 Increments in TNS consumption (g per 1000 kcal of energy intake) were not associated with  
287 significantly greater modified MDS and HDS in consumers. This lack of dose-response relationship  
288 could be due to the low consumption of TNS in the population (for TNS-A consumers, median  
289 0.8% of total energy intake, and 6.5 g/d in terms of total weight intake; for TNS-B consumers, 2.3%  
290 of total energy intake, and 14.0 g/d in terms of total weight intake). TNS consumption status may be  
291 an indicator of improved overall diet quality, but the actual amount consumed has very little  
292 practical impact.

293 Since TNS consumption status appears to act as a marker of healthy dietary patterns, it is not  
294 surprising that the overall nutrient intake profile of TNS consumers was more favourable compared  
295 to non-consumers. The contribution of non-milk extrinsic sugar intakes to energy was only  
296 marginally lower in TNS consumers (a difference of 1.0% of energy). Fibre (non-starch  
297 polysaccharides) intakes were 1.8 g higher in TNS consumers compared with non-consumers, but  
298 TNS intake is unlikely to contribute more than a third of this difference, with the remainder due to  
299 greater intakes of other fibre-rich foods.

300 The observations reported here and in the US population imply that TNS are usually eaten as a  
301 part of an overall healthier dietary pattern in industrialised countries<sup>(21)</sup>, which would be predicted  
302 to translate to better cardiovascular health outcomes. UK TNS consumers had significantly reduced  
303 BMI, WC, SBP and DBP, and significantly higher HDL-C but the slightly lower mean CRP in TNS  
304 consumers did not reach statistical significance compared with non-consumers. O'Neil *et al.*(2015)  
305 previously reported that  $\geq 7.08$  g tree nut consumption was associated with lower BMI and WC, as  
306 well as SBP and higher HDL-C, in the US adult population adjusted for the same covariates as used  
307 in the present analysis, plus physical activity level<sup>(20)</sup>. Feeding trials overall have reported that  
308 higher tree nut consumption did not result in weight gain<sup>(18,19)</sup>, which may be related to their  
309 satiating/satiety-inducing properties<sup>(36)</sup>, as well as limited lipid bioaccessibility<sup>(37)</sup>. Since TNS  
310 consumers' median intake was low in the UK, observed differences in BMI and WC could be  
311 related to confounding factors such as physical activity levels, which was not considered in the  
312 present analysis due to lack of available data. Mean SBP was 4.3 mm Hg lower and mean DBP was  
313 2.8 mmHg lower in TNS consumers compared to non-consumers, a clinically meaningful difference  
314 that would be predicted to reduce risk of CVD. The SUN prospective cohort study reported there  
315 was no association between tree nut consumption and blood pressure; the potential reasons could be  
316 an underestimated amount of nut consumption, no assessment on the change in nut consumption

317 during follow-up, and no specific information on preparation method, e.g. salted, roasted or raw<sup>(38)</sup>.  
318 The Physician's Health Study observed blood pressure reduction only in lean volunteers<sup>(39)</sup>. A  
319 recent meta-analysis of 21 randomised control trials reported that total nut consumption lowered  
320 SBP in participants without type 2 diabetes, and mixed nuts also lowered DBP<sup>(40)</sup>. Although plasma  
321 CRP concentrations were not significantly different in the NDNS cohort, a cross-sectional study  
322 using data from the Nurse's Health Study and Health Professional Follow-Up Study revealed that  
323 consumers eating tree nuts  $\geq 5$  times weekly based on Food Frequency Questionnaire (FFQ) had  
324 significantly lower CRP<sup>(41)</sup>, suggesting larger differences in intake may be required to impact on  
325 systemic inflammatory markers. However, a meta-analysis of 20 randomised controlled trials  
326 suggested that tree nut consumption did not reduce CRP<sup>(42)</sup>. In the current study, the amount of nuts  
327 consumed by consumers in the current UK cohort was low, and therefore the SBP and DBP  
328 differences observed are likely to be the sum effect of an overall healthier dietary pattern including  
329 TNS<sup>(43-46)</sup>.

330 **A significant difference was observed in HDL-C between TNS consumers and non-consumers.**  
331 **Cross-sectional analysis in the US adult population also reported higher HDL-C in TNS**  
332 **consumers<sup>(20)</sup>. There were no significant differences observed in other blood lipids.** A recent meta-  
333 analysis of 61 interventional clinical trials revealed that tree nut intake reduced TC, TAG and LDL-  
334 C and it was reported that the dosage of tree nut intake determined cholesterol lowering capacity  
335 rather than the nut types<sup>(47)</sup>. A pooled analysis of 25 feeding trials conducted in seven countries  
336 demonstrated the reduction of TC, LDL-C and the ratio of TC to HDL-C but failed to report the  
337 increase of HDL-C in response to tree nut intake<sup>(48)</sup>. These inconsistent associations of tree nut  
338 consumption and blood pressure, CRP and blood lipids between cross-sectional analysis and  
339 clinical trials could be due to different dosage and duration of consumption (duration of the study),  
340 residual confounding effects, **characteristics such as baseline lipid profile, as well as study sample**  
341 **size relating to statistical power<sup>(41)</sup>.**

342 Strengths of this study include using a relatively large, nationally representative UK  
343 population, and the close agreement with results reported in a nationally representative US  
344 population suggest that findings may be generalisable to other industrialised countries with similar  
345 dietary profiles. The availability of estimated portion size food diary data over a 4-day period is  
346 considered to be one of the more accurate dietary assessment methods in large populations,  
347 although under-reporting of energy intake is a well-known problem with this methodology that  
348 limits the conclusions that can be drawn. Furthermore, the use of 4-d estimated food diaries means  
349 that significant nut intakes on other days may have been missed and a significant proportion of TNS  
350 consumers may have been wrongly classified as non-consumers; analysis based on frequency of  
351 tree nut consumption was not possible. **Available information on physical activity was incomplete**

352 so statistical analysis models could not be adjusted for this potentially confounding factor. Different  
353 types of tree nuts have differing nutrient profiles and potentially nutrient bioaccessibility, and  
354 therefore it may be misleading to group them altogether in terms of associations with cardiovascular  
355 disease risk factors. In addition to that, missing data for cardiovascular disease risk factors resulted  
356 in lower sample sizes.

357 In conclusion, the prevalence of TNS consumers in the UK adult population is estimated to be  
358 approximately 10%, and median intakes were low in the group classified as TNS consumers. TNS  
359 consumption was associated with higher diet quality scores and a more favourable nutrient intake  
360 profile. TNS consumption may be a marker of a healthy dietary pattern and is associated with lower  
361 adiposity, and blood pressure. It is recommended that tree nuts should replace high refined  
362 carbohydrate-based snacks as part of a healthy diet. To determine the relative contribution of tree  
363 nuts to the sum impact of a healthier dietary pattern on risk of CVD, future randomized controlled  
364 trials should investigate the effect of replacing usual refined carbohydrate snacks with tree nuts on  
365 markers of cardiometabolic disease risk.

366

367

368

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Table 1. Background characteristics of tree nut snack (TNS) consumers compared to non-consumers in the UK adult population (≥19 y) based on NDNS 2008-2014, n = 4,738.

		TNS-A			TNS-B		
		Consumer, n = 484	Non-consumer, n = 4,254	p-value	Consumer, n = 224	Non-consumer, n = 4,514	p-value
Amount of tree nuts consumed (Median (IQR))	Gram	6.5 (10.8)			14.0 (10.6)		
	% total energy intake	0.8 (2.2)			2.3 (5.1)		
Age (median (IQR))		51 (24)	48 (27)	<0.001*	53 (24)	48 (27)	<0.001*
Sex	Male (%)	31.1	41.6	<0.001*	32.8	40.8	<0.001*
	Female (%)	68.9	58.4		67.2	59.2	
Ethnicity	White (%)	87.8	93.8		88.9	93.4	
	Mixed ethnic group (%)	1.7	0.9		0.9	1.0	
	Black or Black British (%)	1.6	2.0	0.003*	1.7	1.9	0.016*
	Asian or Asian British (%)	5.9	2.2		5.4	2.4	
Region	Any other group (%)	3.1	1.2		3.0	1.3	
	England (%)	68.1	54.8		64.8	55.8	
	Scotland (%)	11.9	17.9	0.003*	11.9	17.5	0.131
	Wales (%)	12.5	14.8		16.7	14.4	
	Northern Ireland (%)	7.5	12.6		6.6	12.3	
Socio-	Higher managerial and	27.2	13.7	<0.001*	25.9	14.6	<0.001*

economic status	professional occupations (%)						
	Lower managerial and professional occupations (%)	31.2	23.1		26.4	23.9	
	Intermediate occupations (%)	8.2	10.5		9.7	10.3	
	Small employers and own account workers (%)	11.0	10.4		11.1	10.4	
	Lower supervisory and technical occupations (%)	6.5	9.5		7.0	9.3	
	Semi-routine occupations (%)	9.4	15.1		13.2	14.6	
	Routine occupations (%)	3.4	12.9		4.5	12.2	
	Never worked (%)	1.3	3.1		0.7	3.0	
	Other (%)	1.9	1.7		1.5	1.8	
	Current smoker (%)	11.7	25.0		12.5	24.2	
Smoking status	Ex-Regular smoker (%)	25.7	23.6	<0.001*	27.3	23.7	<0.001*
	Never regular smoker (%)	62.6	51.4		60.2	52.2	
Alcohol intake (g/d) (median (IQR))		6.0 (18.4)	0.7 (16.7)	0.012*	4.4 (17.0)	1.8 (16.9)	0.002*
Energy intake (kcal/d) ( <b>unadjusted</b> mean $\pm$ SD))		1900.3 $\pm$ 483.7	1750.8 $\pm$ 565.1	<0.001*	1952.4 $\pm$ 498.8	1756.8 $\pm$ 560.4	<0.001*

This is a descriptive table. Survey-adjusted GLM with a linear binary logistic function was used to investigate the association between TNS consumption and demographic variables.

\*p was <0.05 indicating a significant association.

Table 2. Energy, macro- and micronutrient intake of tree nut snack consumers defined by any amount of daily consumption or  $\geq 7.08$  gram consumption per day, in the UK adult population ( $\geq 19$  y) based on NDNS 2008-2014, n=4,738

Macronutrient (diet only, % food energy) <sup>a</sup>	Estimated marginal mean (95% CI)					
	TNS-A		P-value	TNS-B		P-value
	Consumers, n = 484	Non-consumers, n = 4,254		Consumers, n = 224	Non-consumers, n = 4,514	
Total energy (kcal)	1760.3 (1514.3, 2006.2)*	1565.0 (1322.3, 1807.6)	<0.001	1823.2 (1573.0, 2073.5)*	1621.1 (1379.5, 1862.7)	<0.001
Food energy (kcal)	1703.4 (1471.3, 1935.6)*	1523.4 (1294.3, 1752.4)	<0.001	1772.9 (1536.8, 2008.9)*	1572.7 (1344.8, 1800.5)	<0.001
Protein	17.4 (15.5, 19.2)	17.3 (15.5, 19.2)	0.827	17.5 (15.7, 19.4)	17.3 (15.5, 19.1)	0.384
Fat	37.1 (34.2, 40.0)*	35.1 (32.2, 38.0)	<0.001	37.6 (34.7, 40.5)*	35.2 (32.3, 38.0)	<0.001
Saturated fatty acids	12.2 (10.6, 13.7)*	12.5 (11.0, 14.0)	0.035	11.8 (10.2, 13.3)*	12.3 (10.8, 13.9)	0.008
cis-Monounsaturated fatty acids	14.3 (13.0, 15.6)*	13.0 (11.8, 14.3)	<0.001	15.0 (13.6, 16.3)*	13.1 (11.8, 14.4)	<0.001
cis n-6 fatty acids	6.2 (5.5, 6.9)*	5.3 (4.6, 6.0)	<0.001	6.6 (5.8, 7.3) *	5.4 (4.7, 6.1)	<0.001
cis n-3 fatty acids <sup>0</sup>	1.1 (0.9, 1.3)*	1.0 (0.8, 1.2)	<0.001	1.0 (0.8, 1.1)	1.0 (0.9, 1.1)	0.469
Trans fatty acids	0.5 (0.4, 0.7)*	0.6 (0.5, 0.7)	<0.001	0.5 (0.3, 0.6)*	0.6 (0.4, 0.7)	<0.001
Carbohydrate	45.6 (42.4, 48.8)*	47.6 (44.4, 50.8)	<0.001	44.9 (41.7, 48.2)*	47.6 (44.4, 50.7)	<0.001
Total sugars	17.7 (14.5, 20.9)	17.2 (14.1, 20.4)	0.139	18.1 (14.9, 21.4)	17.8 (14.6, 20.9)	0.399
Starch	27.9 (25.1, 30.6)*	30.3 (27.6, 33.0)	<0.001	26.7 (24.0, 29.5)*	29.8 (27.1, 32.4)	<0.001

Non-milk extrinsic sugars	7.7 (4.7, 10.7)*	8.7 (5.8, 11.7)	0.001	7.5 (4.4, 10.5)*	9.0 (6.1, 11.9)	<0.001
Intrinsic milk sugars and starch	37.8 (34.8, 40.9)*	38.8 (35.8, 41.9)	0.001	34.3 (32.5, 36.2)*	35.9 (34.4, 37.6)	0.003
Intrinsic milk <sup>0</sup> sugars <sup>0</sup>	10.0 (8.2, 11.8)*	8.5 (6.8, 10.3)	<0.001	9.9 (8.1, 12.1)*	7.9 (6.5, 9.6)	<0.001
Non-starch polysaccharides (Englyst Fibre, g)	15.1 (13.2, 16.9)*	13.3 (11.4, 15.1)	<0.001	15.8 (13.9, 17.7)*	13.7 (11.9, 15.5)	<0.001
Alcohol (g) <sup>†, 0</sup>	12.1 (8.8, 16.5)	12.9 (9.6, 17.5)	0.290	10.0 (7.1, 14.0)*	12.7 (9.6, 16.9)	0.013
<b>Micronutrients<sup>b</sup></b>						
Vitamin A (retinol equivalents) (µg) <sup>†, 0</sup>	904.9 (753.4, 1086.9)*	828.9 (696.5, 986.5)	0.024	966.1 (794.0, 1175.2)	885.5 (750.9, 1044.2)	0.128
Vitamin D (µg) <sup>†, 0</sup>	2.5 (2.1, 3.0)	2.4 (2.0, 2.8)	0.213	2.4 (2.0, 2.9)	2.4 (2.0, 2.8)	0.912
Vitamin E (mg) <sup>0</sup>	11.6 (10.1, 13.0)*	9.8 (8.4, 11.2)	<0.001	11.6 (10.6, 12.7)*	9.3 (8.6, 10.1)	<0.001
Thiamin (mg)	1.4 (1.2, 1.6)*	1.3 (1.1, 1.5)	0.001	1.5 (1.3, 1.7)*	1.3 (1.1, 1.5)	<0.001
Riboflavin (mg)	1.5 (1.2, 1.7)	1.4 (1.2, 1.7)	0.196	1.5 (1.3, 1.8)*	1.4 (1.2, 1.7)	0.003
Niacin equivalent (mg)	33.5 (28.7, 38.3)	33.8 (29.1, 38.6)	0.486	34.4 (29.5, 39.3)	33.8 (29.1, 38.5)	0.382
Vitamin B6 (mg) <sup>0</sup>	1.9 (1.5, 2.3)	1.9 (1.5, 2.3)	0.992	1.9 (1.7, 2.1)	1.9 (1.8, 2.1)	0.530
Vitamin B12 (µg) <sup>†, 0</sup>	4.6 (3.6, 6.0)	4.7 (3.7, 6.0)	0.777	4.5 (3.9, 5.2)	4.8 (4.3, 5.5)	0.154
Folate (µg)	242.3 (201.9, 282.6)*	229.4 (189.5, 269.2)	0.001	255.7 (214.7, 296.6)*	237.0 (197.5, 276.6)	0.001
Pantothenic acid (mg)	5.6 (4.6, 6.5)	5.3 (4.4, 6.3)	0.007	5.9 (4.9, 6.8)*	5.3 (4.4, 6.2)	<0.001
Biotin (µg)	36.4 (30.1, 42.7)*	30.0 (23.8, 36.3)	<0.001	41.3 (34.9, 47.6)*	31.7 (25.5, 37.9)	<0.001

Vitamin C (mg) <sup>†, θ</sup>	79.1 (58.4, 107.3)*	62.1 (46.0, 83.8)	<0.001	90.4 (75.3, 108.6)*	79.0 (67.8, 92.3)	0.012
Sodium (mg)	1854.8 (1596.0, 2113.6)*	2053.9 (1798.5, 2309.3)	<0.001	1732.2 (1469.6, 1994.8)*	2006.2 (1752.6, 2259.8)	<0.001
Potassium (mg)	2866.7 (2595.1, 3138.2)*	2645.3 (2377.3, 2913.3)	<0.001	3021.3 (2746.0, 3296.6)*	2694.8 (2428.8, 2960.5)	<0.001
Calcium (mg)	696.6 (591.3, 801.8)	702.8 (599.0, 806.7)	0.541	717.4 (610.8, 824.0)	709.6 (606.7, 812.6)	0.599
Magnesium (mg)	276.9 (251.0, 302.8)*	237.8 (212.3, 263.4)	<0.001	301.5 (275.3, 327.8)*	245.3 (219.9, 270.6)	<0.001
Phosphorus (mg)	1165.8 (1056.1, 1275.6)*	1125.4 (1017.1, 1233.7)	<0.001	1191.5 (1080.3, 1302.6)*	1126.2 (1018.9, 1233.5)	<0.001
Iron (mg)	11.1 (9.9, 12.4)*	10.4 (9.1, 11.6)	<0.001	11.2 (9.9, 12.4)*	10.5 (9.3, 11.7)	<0.001
Copper (mg) <sup>†, θ</sup>	1.2 (1.0, 1.4)*	1.0 (0.9, 1.2)	<0.001	1.4 (1.3, 1.6)*	1.2 (1.1, 1.3)	<0.001
Zinc (mg)	9.0 (7.9, 10.0)*	8.8 (7.7, 9.8)	0.044	9.3 (8.2, 10.3)*	8.8 (7.8, 9.8)	0.002
Chloride (mg)	3017.1 (2631.3, 3402.9)*	3286.7 (2906.0, 3667.5)	<0.001	2877.8 (2486.4, 3269.1)*	3242.2 (2864.3, 3620.1)	<0.001
Manganese (mg)	3.3 (2.8, 3.8)*	2.8 (2.3, 3.3)	<0.001	3.5 (3.0, 4.0)*	2.9 (2.4, 3.4)	<0.001
Iodine (µg)	161.9 (131.1, 192.7)	158.7 (128.3, 189.1)	0.282	158.2 (127.0, 189.4)	158.6 (128.5, 188.8)	0.914
Selenium (µg) <sup>θ</sup>	56.9 (48.3, 65.4)*	51.9 (43.4, 60.3)	<0.001	54.9 (49.8, 60.5)*	50.5 (46.6, 54.8)	0.004

The actual sample size in the computation for vitamin A and vitamin D, for TNS-A consumers was 314 and for TNS-A non-consumers was 2,172, whereas for TNS-B consumers was 138 and for TNS-B non-consumers was 2,348. The actual sample size in the computation for alcohol, cis-n3 fatty acids, intrinsic milk sugars and starch, vitamin E, vitamin B6, vitamin B12, vitamin C, copper and selenium for TNS-B consumers was 138 and for TNS-B non-consumers was 2,348. There were no missing values in the computation for other nutrients as outcomes.

\* p<0.05 showed a significant difference

<sup>†</sup>Geometric marginal means were presented due to non-normally distributed residual data in TNS-A population.

<sup>‡</sup>Geometric marginal means were presented due to non-normally distributed residual data in TNS-B population.

*a* Survey-adjusted GLM with a linear link function and predictors: age, sex, ethnicity, region of residency, socio-economic and smoking status was used for energy intake as an outcome for TNS-A; Survey-adjusted GLM with a linear link function and predictors: age, sex, ethnicity, region of residency, socio-economic and smoking status, alcohol and energy intakes was used for other macronutrient intake outcomes for TNS-A; Survey-adjusted GLM with a linear link function and predictors: age, sex, ethnicity, region of residency, socio-economic and smoking status, and energy intake was used for alcohol intake as an outcome for TNS-A. The same statistical analysis was conducted for TNS-B but region of residency was excluded from predictors.

*b* Survey-adjusted GLM with a linear link function and predictors: age, sex, ethnicity, region of residency, socio-economic and smoking status, alcohol and energy intakes was used for TNS-A. The same statistical analysis was conducted for TNS-B but region of residency was excluded from predictors.

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Table 3. Cardiovascular disease risk marker values in UK adults ( $\geq 19$  y) based on NDNS 2008-2014, in consumers of any amount of tree nut snack and non-consumers, and the association of tree nut snack consumption and risk markers.

CVD risk marker	Value <sup>a</sup>		<i>P</i> -value	Associations between tree nut consumption and CVD risk markers <sup>b</sup>		
	(Estimated marginal mean (95% CI))			$\beta$ (95% CI)	<i>P</i> -value	<i>R</i> <sup>2</sup>
	Consumers	Non-consumer				
BMI (kg/m <sup>2</sup> ) <sup>c, †</sup>	25.4 (24.0, 26.8)	26.3 (25.0, 27.8)	0.002*	1.035 (0.991, 1.081)	0.128	0.121
WC (cm) <sup>d</sup>	91.5 (88.5, 94.6)	94.2 (91.5, 97.0)	<0.001*	0.094 (-0.080, 0.268)	0.289	0.293
SBP (mmHg) <sup>e</sup>	119.7 (116.2, 123.2)	124.0 (120.8, 127.1)	<0.001*	-0.242 (-0.458, -0.026)	0.028*	0.286
DBP (mmHg) <sup>e</sup>	69.2 (66.8, 71.7)	72.0 (69.7, 74.2)	<0.001*	-0.034 (-0.196, 0.127)	0.677	0.033
TC (mmol/l) <sup>f</sup>	4.9 (4.5, 5.3)	4.9 (4.5, 5.3)	0.627	0.011 (-0.007, 0.029)	0.218	0.109
TAG (mmol/l) <sup>g, †</sup>	1.1 (0.9, 1.3)	1.1 (0.9, 1.4)	0.220	0.972 (0.813, 1.164)	0.757	0.084
HDL-C (mmol/l) <sup>f</sup>	1.5 (1.4, 1.7)	1.4 (1.3, 1.6)	0.008*	-0.001 (-0.009, 0.007)	0.754	0.277
LDL-C (mmol/l) <sup>h</sup>	2.9 (2.6, 3.3)	2.9 (2.6, 3.2)	0.980	0.011 (-0.006, 0.028)	0.204	0.046
TC:HDL-C <sup>f</sup>	3.5 (3.1, 4.0)	3.6 (3.2, 4.0)	0.412	0.016 (-0.005, 0.037)	0.143	0.163
CRP (mg/l) <sup>i, †</sup>	1.9 (1.3, 2.6)	2.1 (1.5, 2.9)	0.062	1.194 (0.933, 1.528)	0.157	0.095

*a* Survey-adjusted GLM with a linear link function and predictors: age, sex, ethnicity, region of residency, socio-economic and smoking status, alcohol and energy intakes was used.

*b* Survey-adjusted multivariable linear regression was used, adjusted for age, sex, ethnicity, region of residency, socio-economic and smoking status and alcohol intake.

\* $p < 0.05$  showed a significant difference.

†Geometric marginal means and geometric  $\beta$  (95% CI) values were presented due to non-normally distributed residual data. Geometric  $\beta$  values were interpreted as ratios of geometric means.

Due to missing data, sample sizes were as follows: TNS-A consumers 241<sup>c</sup>, 384<sup>d</sup>, 326<sup>e</sup>, 274<sup>f</sup>, 176<sup>g,i</sup>, and 273<sup>h</sup>; non-consumers 1,616<sup>c</sup>, 3,110<sup>d</sup>, 2,456<sup>e</sup>, 2,132<sup>f</sup>, 1,161<sup>g</sup>, 2,096<sup>h</sup>, and 1,164<sup>i</sup>.

For Peer Review



## Appendix A: Diet quality scores

Table A1. Original and modified Mediterranean Diet Score (MDS) and its scoring system<sup>(24)</sup>

Food group		Scoring*	
Original MDS	Modified MDS		
Cereals	Cereals	>median	1 (else: 0)
Vegetables	Vegetables	>median	1 (else: 0)
<b>Fruits and Nuts</b>	<b>Fruits</b>	>median	1 (else: 0)
Legumes	Legumes	>median	1 (else: 0)
Fish	Fish	>median	1 (else: 0)
Meat	Meat	<median	1 (else: 0)
Dairy products	Dairy products	<median	1 (else: 0)
Ratio of unsaturated to saturated fats	Ratio of unsaturated to saturated fats	>median	1 (else: 0)
Alcohol	Alcohol	10-50 g/d for men	1 (else: 0)
		5-25 g/d for women	1 (else: 0)

\*Except alcohol, scoring of each food group is based on population and sex-specific median.

Table A2. Original and modified Healthy Diet Score (HDS) and the cut-off values for scoring<sup>(25)</sup>

HDS			HDS – modified based on current UK recommendations		
Index item	Cut-off values		Index item	Cut-off values	
	Score 1	Score 0		Score 1	Score 0
Saturated fatty acids (% energy intake)	0-10	>10	Saturated fatty acids (% energy intake)	0-11 <sup>a</sup>	>11
Polyunsaturated fatty acids (% energy intake)*	6-10	<6 or >10	Polyunsaturated fatty acids (% energy intake)	6 <sup>b</sup> -10	<6 or >10
Protein (% energy intake)	10-15	<10 or >15	Protein (% energy intake)	9 <sup>c</sup> -15	<9 or >15
Total carbohydrate (% energy intake)*	50-70	<50 or >70	Total carbohydrate (% energy intake)	50 <sup>d</sup> -70	<50 or >70
Dietary fibre (g)*	18-32	<18 or >32	Dietary fibre (g)	18 <sup>d</sup> -32	<18 or >32
Fruits and vegetables (g)	≥400	<400	Fruits and vegetables (g)	≥400 <sup>e</sup>	<400

Pulses and nuts (g)*	≥30	<30	Pulses (g)	≥30	<30
Total non-milk extrinsic sugar (% total energy intake)*	0-10	>10	Total non-milk extrinsic sugar (% total energy intake)	0-5 <sup>d</sup>	>5
Cholesterol (mg)*	0-245	>245	Trans-fatty acids (% energy intake)	≤2 <sup>e</sup>	>2
Fish (g)*	≥32	<32	Fish (g)	≥40 <sup>e</sup>	<40
Red meat and meat processed products (g)*	≤90	>90	Oily fish (g)	≥20 <sup>e</sup>	<20
Calcium (mg)*	≥700	<700	Red meat and meat processed products (g)	≤70 <sup>i</sup>	>70
			Calcium (mg)	≥700 <sup>c</sup>	<700
			Sodium (mg)	≤2400 <sup>c</sup>	>2400

\* Items based on advice on healthy eating as recommended by the UK Committee on Medical Aspects of Food Policy (COMA)<sup>(25)</sup>

*a* Based on NDNS Results from Years 5 and 6 (combined) of the Rolling Programme (2012/2013 – 2013/2014)<sup>(22,23)</sup>, UK Government Dietary Recommendations by Public Health England (2016)<sup>(26)</sup>, Cardiovascular Disease Outcomes Strategy by UK Department of Health (2013)<sup>(27)</sup> and Draft report: Saturated fats and health by Scientific Advisory Committee on Nutrition (SACN) 2018<sup>(29)</sup>

*b* Based on UK Government Dietary Recommendations by Public Health England (2016)<sup>(26)</sup>

*c* Based on UK Government Dietary Recommendations by Public Health England (2016)<sup>(26)</sup>

*d* Based on UK Government Dietary Recommendations by Public Health England (2016)<sup>(26)</sup> and Scientific Advisory Committee on Nutrition (SACN) Report 2015 on Carbohydrates and Health<sup>(30)</sup>

*e* Based on NDNS Results from Years 5 and 6 (combined) of the Rolling Programme (2012/2013 – 2013/2014)<sup>(22,23)</sup> and The Eatwell Guide by Public Health England (2016)<sup>(28)</sup>

## Appendix B: Associations between tree nut consumption ( $\geq 7.08$ g) and CVD risk markers

Table B1. Cardiovascular disease risk marker values in UK adults ( $\geq 19$  y) based on NDNS 2008-2014,  $n = 4,738$ , in consumers of  $\geq 7.08$  g of tree nut snack and non-consumers.

CVD risk marker	Value <sup>a</sup> (Estimated marginal mean (95% CI))		P-value
	Consumers, n=224	Non-consumer, n=4,514	
BMI (kg/m <sup>2</sup> ) <sup>b, †</sup>	26.0 (24.4, 27.6)	26.1 (24.8, 27.5)	0.705
WC (cm) <sup>c</sup>	91.6 (88.3, 94.9)	94.0 (91.2, 96.8)	0.015*
SBP (mmHg) <sup>d</sup>	118.3 (114.5, 122.2)	123.7 (120.5, 126.9)	<0.001*
DBP (mmHg) <sup>d</sup>	69.3 (66.5, 72.0)	71.7 (69.4, 74.0)	0.005*
TC (mmol/l) <sup>e</sup>	5.0 (4.6, 5.4)	4.9 (4.5, 5.3)	0.299
TAG (mmol/l) <sup>f, †</sup>	1.1 (0.8, 1.4)	1.1 (0.9, 1.4)	0.424
HDL-C (mmol/l) <sup>e</sup>	1.5 (1.4, 1.7)	1.5 (1.3, 1.6)	0.053
LDL-C (mmol/l) <sup>g</sup>	2.9 (2.6, 3.3)	2.9 (2.6, 3.2)	0.531
TC:HDL-C <sup>e</sup>	3.6 (3.1, 4.0)	3.6 (3.2, 4.0)	0.924
CRP (mg/l) <sup>h, †</sup>	2.0 (1.4, 2.8)	2.0 (1.5, 2.8)	0.685

<sup>a</sup> Survey-adjusted GLM with a linear link function and predictors: age, sex, ethnicity, socio-economic and smoking status, alcohol and energy intakes was used.

<sup>†</sup>Geometric marginal means were presented due to non-normally distributed residual data.

Due to missing data, sample sizes were as follows: TNS-B consumer 110<sup>b</sup>, 186<sup>c</sup>, 162<sup>d</sup>, and 138<sup>e,g</sup>, 86<sup>f,h</sup>, non-consumers 1,747<sup>a</sup>, 3,308<sup>c</sup>, 2,620<sup>d</sup>, 2,268<sup>e</sup>, 1,251<sup>f</sup>, 2,231<sup>g</sup>, and 1,254<sup>h</sup>.