

1 This is the author's accepted manuscript. The final published version of this work (the version of
2 record) is published by Wiley in *Journal of Human Nutrition and Dietetics*, 22 Jun 2017 available at:
3 10.1111/jhn.12489. This work is made available online in accordance with the publisher's policies. Please refer
4 to any applicable terms of use of the publisher.

5

6 **Deprivation and Healthy Food Access, Cost and Availability: A Cross-Sectional Study**

7 Sarah. Williamson, M. McGregor-Shenton, B. Brumble, B. Wright, & C. Pettinger.

8 School of Health Professions, Plymouth University, Drake Circus, Plymouth, UK

9

10 **Key terms:** Healthy Food Access, Food Deserts, Food Retail Mapping, Healthy Food Basket Survey,
11 Socioeconomic Inequalities in Food Retail.

12

13 **Authors contributions:** Sarah Williamson: conducted data collection, statistical analysis and led the
14 journal write up; Megan McGregor-Shenton: conducted data collection, statistical analysis, proof
15 reading and assisted with the journal write up; Bessie Brumble: conducted data collection, statistical
16 analysis and proof reading; Bernice Wright: conducted data collection, statistical analysis and proof
17 reading; Clare Pettinger: provided supervision and feedback throughout the study and assisted with
18 the journal write up.

19

20 **Word Count:** 3174.

21 **Conflict of interest:** None.

22

23 **Corresponding author (and person to whom reprint requests should be addressed):** Clare
24 Pettinger, School of Health Professions, Plymouth University, Drake Circus, Plymouth, UK.

25 **Phone:** 01752 588822 **Fax:** 01752 588874 **Email:** clare.pettinger@plymouth.ac.uk

26

27

28

29

30 **Abstract**

31 **Background:** Food access, cost and availability have been identified as determinants of dietary
32 choice. It has been suggested that these are socioeconomically patterned, however the evidence is
33 inconclusive. This study investigated whether differences exist in the access to, and cost and
34 availability of healthy food between areas of contrasting deprivation.

35 **Methods:** An ecological, cross-sectional study was conducted in two of the most and two of the least
36 deprived wards in Plymouth. Food retail outlets (FROs) ($n=38$) were identified and mapped using
37 Geographic Information Systems (GIS) to assess 'physical access', by foot, to food retail provision.
38 Healthy food basket (HFB) surveys were conducted ($n=32$) to compare the cost and availability of 28
39 healthy food items between the more and less deprived areas.

40 **Results:** Areas of poor access to food retail provision were identified in both study areas, with a
41 higher number of households in the more-deprived areas being affected than in the less-deprived,
42 after accounting for car ownership levels. Median [IQR] HFB availability was lower in more-
43 deprived than the less-deprived areas (48%, [33%] *vs.* 75%, [14%]; $P=0.003$), and in convenience
44 stores than supermarkets (54%, [29%] *vs.* 78%, [24%]; $P=0.001$). Descriptive summaries revealed
45 negligible differences in total median HFB cost between the more-deprived and less-deprived areas
46 (£55.97 *vs.* £55.94), and a larger cost difference between convenience stores and supermarkets
47 (£62.39 *vs.* £44.25).

48 **Conclusions:** Differences were found in the access to, and cost and availability of healthy foods in
49 areas of contrasting deprivation. These appeared related to FRO type rather than deprivation alone.

50

51

52

53

54

55

56

57

58

59 **Introduction**

60 The ‘food environment’ has been implicated as a critical determinant of food choice⁽¹⁾. If UK diets
61 matched nutritional guidelines, almost 70,000 premature deaths from chronic non-communicable
62 diseases (NCDs) could be prevented annually⁽²⁾. This is particularly pertinent to low socioeconomic
63 groups (LSGs), due to the documented social gradient in the nutritional quality of the diet, finding
64 that those on the lowest incomes consume more salt, sugar and saturated fat, and less fruit and
65 vegetables⁽³⁾. However, dietary choice is multifaceted and complex, due to influences from a range
66 of biological and societal factors⁽⁴⁾. Increasingly, research has focused upon the influence of the food
67 environment on dietary choice, suggesting that food access, cost, and availability may be important
68 determinants of the nutritional quality of the diet⁽⁵⁾.

69 Food access refers to physical access to food retail provision⁽⁵⁾ and is dependent upon geographical
70 location and resources such as transport accessibility⁽⁴⁾. Geographic Information Systems (GIS) is
71 considered useful for assessing food retail access⁽⁶⁾, due its capacity to map and spatially analyse
72 data⁽⁷⁾. Availability refers to the types of food retail outlets (FROs) in a geographical area, and the
73 foods that they sell⁽⁸⁾. Previous research has measured the availability and cost of healthy food items
74 using Healthy Food Basket (HFB) surveys^(9,10), which have been found to have sufficient sensitivity
75 to discriminate well between stores⁽⁹⁾.

76 It has been suggested that food access, cost and availability are socioeconomically patterned, with
77 research from the United States (US) finding that lower income areas have lower access to healthy
78 foods⁽¹¹⁾. Specifically, it was observed that the FROs in these areas offered lower healthy food
79 availability, whilst also charging higher prices^(12,13). Areas where it is difficult to purchase healthy
80 food items at a reasonable price are referred to as ‘Food Deserts’⁽¹³⁾. The existence of Food Deserts
81 is widely accepted in the US⁽¹⁴⁾, however is vigorously debated in the literature elsewhere^(13,15).

82 In the United Kingdom (UK), a comprehensive review of the evidence concluded that “Food Deserts
83 do exist in the UK, but only for individuals who do not or cannot shop outside of their immediate
84 locality, and when the locality itself has poor retail provision of healthy foods”⁽¹³⁾. It has previously
85 been shown that deprived areas have reduced access to shopping facilities⁽¹⁶⁾, which has been
86 attributed to the rise of large, out-of-town superstores that tend to favour car owners⁽¹⁷⁾. As those from
87 LSGs are less likely to own a car⁽¹⁸⁾, this supports the existence of a social gradient regarding healthy
88 food retail provision. However, a more recent systematic review contradicted this finding, concluding
89 that unsubstantial evidence exists to suggest that food access is socioeconomically-patterned in the
90 UK⁽¹⁴⁾. Research into the relationship between the food retail environment and dietary intake is still
91 underdeveloped in the UK⁽⁵⁾, and therefore the evidence remains inconclusive.

92 It is clear that more UK-specific research is needed regarding healthy food provision in the food retail
93 environment. Therefore, this study aims to explore whether the level of deprivation affects the access
94 to, and the cost and availability of, foods representative of a healthy diet.

95

96

97

98

99

100

101

102

103

104

105

106

107

108

109

110

111

112

113

114

115

116 **Methods**

117 **Study Design**

118 This exploratory ecological cross-sectional study investigated healthy food retail access in areas of
119 contrasting deprivation in Plymouth; a South West UK coastal city. FROs were identified using
120 primary and secondary data sources, and were mapped using GIS to determine areas of poor physical
121 access, by foot, to food retail provision. Healthy food availability and cost were assessed and
122 compared using a HFB survey. All data were collected during one week in May 2016, to minimise
123 seasonable variations in food availability and cost.

124

125 **Food Retail Outlets**

126 In line with previous research, the food retail environment was investigated and compared at electoral
127 ward level^(19,20,21). The Indices of Multiple Deprivation (IMD) Electoral Wards Rank⁽²²⁾ was used to
128 identify two of the most and two of the least deprived of the 20 wards in Plymouth, and were grouped
129 to form two areas of contrasting deprivation. Electoral wards are aggregations of Lower Super Output
130 Areas (LSOAs), which vary in size to maintain an average population of 1500 residents⁽²³⁾. Identified
131 wards in this study included St Budeaux and Honicknowle, ranked the third and fourth most deprived
132 in Plymouth respectively; and Plymstock Dunstone and Plympton St Mary, ranked the two least
133 deprived. The more-deprived area is comprised of 24 LSOAs and has a total population size of
134 28,173⁽²⁴⁾, whilst the less-deprived area, comprised of 21 LSOAs, has a population size of 25,173⁽²⁴⁾.

135 FROs were consecutively sampled from an extensive list of all identified FROs in the four wards,
136 generated using secondary data sources including Local Authority databases, Google Maps, Yell.com,
137 and websites of major food retailers and symbol groups (e.g. Premier). In line with other studies,
138 500m was deemed a reasonable distance to travel to FROs by foot⁽²¹⁾ and thus FROs within 500
139 metres of the ward boundaries were included in the study, because residents on ward boundary edges
140 would still have access to these FROs⁽¹⁹⁾. Included FROs were superstores (25-60,000 sq.ft.),
141 supermarkets (3-25,000 sq.ft.) and convenience stores (<3000 sq.ft.), as defined in the UK by the
142 Institute of Grocery Distribution (IGD)⁽²⁵⁾. All other FROs were excluded, due to the observation that
143 food shopping in England is most commonly completed ‘under one roof’⁽²⁰⁾.

144 To validate the secondary data sources used, all identified FROs were verified visually or by telephone
145 contact, because primary data collection in the form of field work has been identified as the ‘gold
146 standard’ for verifying the food environment⁽²⁶⁾. Due to some identified discrepancies between the

147 classification of FROs on Google and retailers' own websites, the researchers re-classified FROs as
148 per the IGD definitions. The definition of a convenience store is well-established⁽²⁷⁾, however due to
149 practical limitations, store managers were relied upon to verify the classification between supermarket
150 and superstore. From this, the 39 verified FROs were identified and invited to participate in the
151 research. Consent to conduct in-store data collection was sought by postal letter and non-respondents
152 were followed-up in-person.

153 ArcGIS version 10.4⁽²⁸⁾ was used to map the spatial co-ordinates of all 39 verified FROs, and to create
154 500 metre geographical buffer zones around each. Areas within the ward which fell outside of these
155 zones were considered to have poor physical access, by foot, to food retail provision. Census datasets
156 relating to car ownership were also incorporated at LSOA level⁽²⁹⁾. This was to enable a visual
157 appraisal of the percentage of households without car availability, that are located in areas identified
158 to have poor physical access, by foot, to food retail provision.

159

160 **Healthy Food Basket Survey**

161 The cost and availability of 28 healthy foods were measured using a HFB survey (detailed in **Table**
162 **1**); an adaptation of the previously validated Healthy Eating Indicator Shopping Basket⁽³⁰⁾ (HEISB).
163 The intention was to use a range of products representing a healthy, balanced diet, and therefore the
164 adaptations were designed to better reflect the composition of the Eatwell Guide⁽³¹⁾ and the South
165 West UK locality of the study. An adapted version of food item descriptions and list of acceptable
166 substitutions⁽⁹⁾ were used to reduce the risk of systematic error during data collection. The costs of
167 food items were recorded according to the cheapest own-brand product available in the sizes
168 specified⁽⁹⁾. If this information was unavailable, the price-per-kilogram of product was recorded,
169 along with the product weight, to enable the price-per-unit to be calculated. In line with previous
170 research, promotional prices were not recorded⁽¹⁰⁾. Informed, signed consent was sought from FRO
171 managers in order to conduct the surveys.

172

173 **Data processing and analysis**

174 Data were inputted into Microsoft Excel in duplicate, and cross-checked for consistency by another
175 member of the research team to improve the inter-rater reliability. All data analysis was conducted
176 by deprivation level (more-deprived, less-deprived), by FRO type (convenience store, supermarket)
177 and by FRO subtype (more-deprived convenience stores, more-deprived supermarkets, less-deprived

178 convenience stores, less-deprived supermarkets) categories. No superstores were identified in the
179 study areas.

180 Consistent with methodology from similar studies⁽⁹⁾, to enable price comparisons between the HFB
181 items across the FROs, varying product sizes were standardised to the specified unit in the substitution
182 list. For those items without a weight, average weights for these items were determined, using values
183 from three supermarket websites. Due to the small number of stores which stocked the full HFB a
184 full HFB cost was calculated by deprivation level and FRO type using median prices-per-item.

185 The Mann-Whitney U test was conducted to determine differences in percentage HFB availability
186 between deprivation level and FRO type. The Kruskal Wallis ANOVA was also conducted to
187 determine differences in percentage HFB availability between FRO subtype. Dunns Pairwise
188 Comparison with Bonferroni adjustment provided post-hoc analysis⁽³²⁾. Statistical analysis was
189 conducted using Microsoft Excel and IBM SPSS version 22.0⁽³³⁾. Statistical significance was set at
190 $P \leq 0.05$.

191

192 **Ethical Considerations**

193 Ethical approval was granted by the School of Health Professions Bachelor's Degree Ethics
194 Subcommittee. To minimise risk of reputational harm, FRO data remained anonymous throughout
195 the study process.

196

197

198

199

200

201

202

203

204

205

206

207 **Results**

208 **Food Retail Outlets**

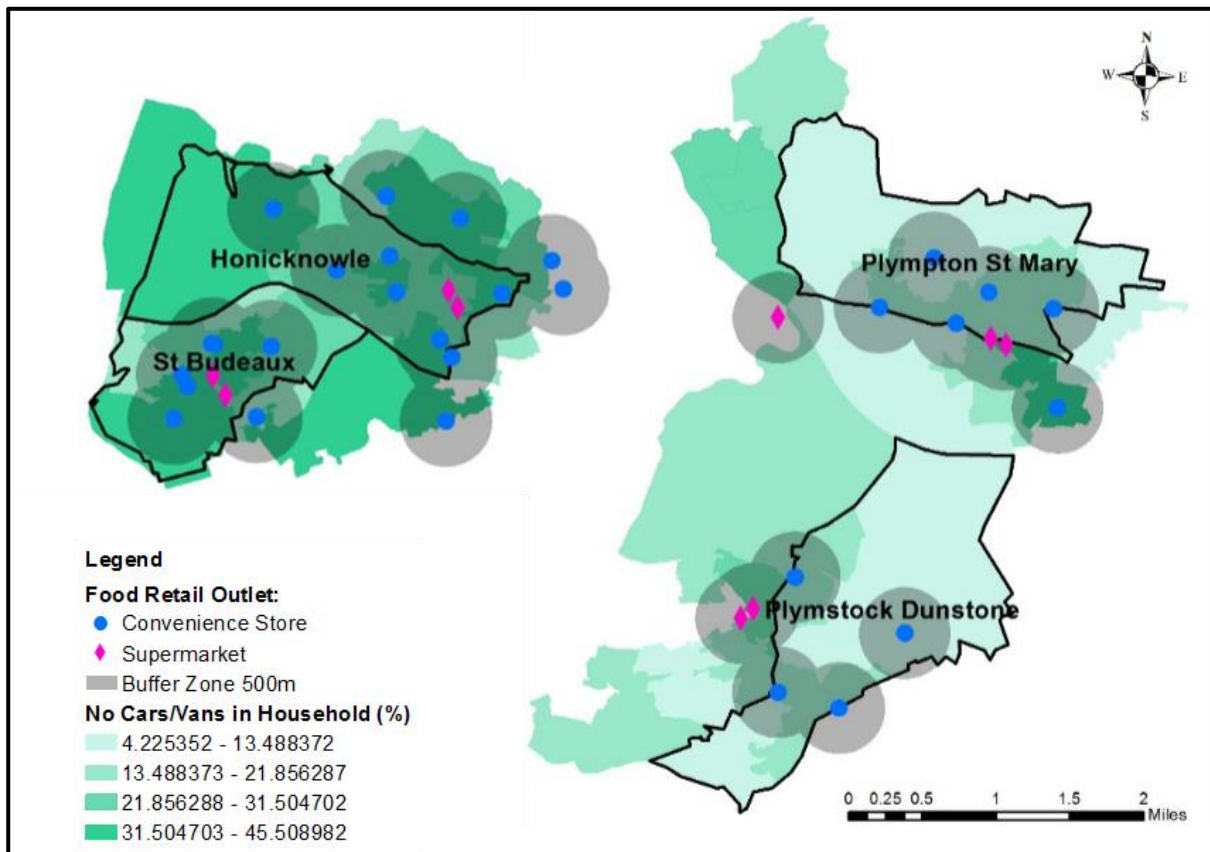
209 Thirty-eight FROs were confirmed within the study areas, of which 32 consented to participate in the
210 HFB survey, five declined, and one was closed for refurbishment at the time of surveying. The
211 proportion of the total number of FROs is higher in the more-deprived than the less deprived areas
212 ($n=23$ (61%) vs. $n=15$ (39%), respectively), with a higher proportion of convenience stores to
213 supermarkets, both in the more-deprived ($n=19$ (83%) vs. $n=4$ (17%), respectively) and less-deprived
214 areas ($n=10$ (67%) vs. $n=5$ (33%), respectively). The six non-participants of the survey were equally
215 matched in terms of deprivation level and FRO type.

216

217 **Access**

218 All identified FROs are shown in **Figure 1**, including 500 metre geographical buffer zones. Areas
219 outside of these buffer zones were deemed to have poor physical access, by foot, to food retail
220 provision. The percentage of households without car availability in these identified areas of poor
221 access ranged from 13% to 46% in the more-deprived areas and 4% to 22% in the less-deprived areas.

222



223

224 **Figure 1** Geographic Information Systems mapping of Food Retail Outlets in the more-deprived
225 areas (Honicknowle and St Budeaux) and the less-deprived areas (Plympton St Mary and Plymstock
226 Dunstone). Areas outside of the geographical buffer zones indicate poor physical access, by foot, to
227 food retail provision, and car ownership data shows the percentage of households without car
228 availability by Lower Super Output Area.

229

230 **Healthy Food Basket Survey**

231 Descriptive summaries revealed negligible differences in median HFB cost between the more-
232 deprived and the less-deprived areas (£55.97 vs. £55.44). However, a larger cost difference was found
233 between convenience stores and supermarkets (£62.39 vs. £44.25). Subgroup analysis found that the
234 median HFB cost was lower in both convenience stores and supermarkets in the more-deprived areas,
235 than in convenience stores and supermarkets in the less-deprived areas (£60.15 and £42.30 vs. £63.60
236 and £45.48, respectively).

237 Across the 32 FROs surveyed, four (13%) stocked all 28 HFB items, whilst 21 (66%) stocked at least
238 half of the HFB. Median [IQR] HFB availability was lower in the more-deprived areas compared to
239 the less-deprived (48% [33%] vs. 75% [14%]; U=195.000, P=0.003), and in convenience stores
240 compared to supermarkets (54% [29%] vs. 78% [24%]; U=153.500, P=0.001). This data is reported
241 in **Table 1**. Median HFB availability differed by FRO subtype ($H^2=16.272$, P=0.001), with the largest
242 difference identified between convenience stores in the more-deprived areas and supermarkets in the
243 less-deprived (P=0.018). Differences in availability were also found between convenience stores in
244 the more-deprived areas and convenience stores in the less-deprived (P=0.044); and between
245 convenience stores in the more-deprived areas and supermarkets in the less-deprived (P=0.047).

246

247

248

249

250

251

252

253

Table 1. Differences in Availability of Healthy Food Basket Items (%) by Deprivation Level and Food Retail Outlet Type.

	Deprivation Level		Food Retail Outlet Type	
	High (n=20)	Low (n=12)	Convenience Store (n=25)	Supermarket (n=7)
Food Item (n=28)	Stocked ^a (n (%))	Stocked ^a (n (%))	Stocked ^a (n (%))	Stocked ^a (n (%))
Brown rolls	13 (65)	13 (65)	18 (72)	7 (100)
Potatoes	19 (95)	19 (95)	24 (96)	7 (100)
Brown rice	4 (20)	4 (20)	5 (20)	3 (57)
White rice	20 (100)	20 (100)	25 (100)	7 (100)
Pasta	20 (100)	20 (100)	25 (100)	7 (100)
Weetabix	18 (90)	18 (90)	22 (88)	7 (100)
Wholemeal bread	15 (75)	15 (75)	20 (80)	7 (100)
Apples	16 (80)	16 (80)	21 (84)	7 (100)
Bananas	14 (70)	14 (70)	19 (76)	7 (100)
Grapes	12 (60)	12 (60)	16 (64)	7 (100)
Orange	10 (50)	10 (50)	14 (56)	7 (100)
Orange juice	19 (95)	19 (95)	24 (96)	7 (100)
Broccoli	10 (50)	10 (50)	14 (56)	7 (100)
Carrots	12 (60)	12 (60)	17 (68)	7 (100)
Cucumber	14 (70)	14 (70)	19 (76)	7 (100)
Lettuce	13 (65)	13 (65)	17 (68)	7 (100)
Onions	20 (100)	20 (100)	25 (100)	7 (100)
Peas	18 (90)	18 (90)	23 (92)	7 (100)
Peppers	13 (65)	13 (65)	18 (72)	7 (100)
Tomatoes	19 (95)	19 (95)	24 (96)	7 (100)
Semi-skimmed milk	20 (100)	20 (100)	25 (100)	7 (100)
Skimmed milk	14 (70)	14 (70)	19 (76)	7 (100)
Low-fat yoghurt	12 (60)	12 (60)	16 (64)	7 (100)
Lean beef mince	3 (15)	3 (15)	2 (8)	6 (86)
Chicken breast	13 (65)	13 (65)	16 (64)	7 (100)
Salmon	6 (30)	6 (30)	8 (32)	7 (100)
Baked beans	20 (100)	20 (100)	25 (100)	7 (100)
Low-fat spread	10 (50)	10 (50)	14 (56)	7 (100)

^a Category consists of groups: ‘in-stock’, ‘out of stock, awaiting delivery’, not stocked but 1st substitute available’, not stocked, but 2nd substitute available’.

254

255

256

257

258

259

260

261

262 Discussion

263 This exploratory study investigated whether deprivation level affects the access to, and cost and
264 availability of healthy foods. Areas of poor physical access, by foot, to food retail provision were
265 identified in both study areas. However, within these areas of poor access, local data shows that more
266 households in the more-deprived areas did not have access to a car or van compared to in the less-
267 deprived⁽²⁹⁾ (see **Figure 1**). Previous research has failed to demonstrate socioeconomic patterning
268 regarding the access to healthy food retail provision⁽³⁴⁾, however it has been found that those living
269 in the more-deprived areas are less likely to have access to a car⁽²⁷⁾. Despite their use of taxis⁽¹³⁾ and
270 online food shopping⁽³⁵⁾, individuals without car access are significantly more likely to travel home
271 from food shopping by foot⁽³⁶⁾. Therefore, they are likely to be particularly susceptible to changes in
272 the local food retail environment regarding the provision of healthy food. Interestingly, the more-
273 deprived areas contained more convenience stores and fewer supermarkets than the less-deprived
274 areas⁽⁹⁾. As less individuals in the more-deprived areas had access to a car or van⁽²⁹⁾, this suggests a
275 heavier reliance upon convenience stores for those living in more-deprived areas.

276 In terms of the cost of healthy food, it was expected to find that convenience stores charged more on
277 average for the full HFB, and that this is supported by existing literature⁽¹³⁾. Therefore, it was
278 surprising that negligible differences were found in the cost of healthy food between the more and
279 the less-deprived areas. Whilst this aligns with findings by White et al.⁽¹³⁾, it contrasts with others in
280 the literature. Dawson et al.⁽⁹⁾ found that healthy food cost less in less deprived areas, whilst Cummins
281 and McIntyre⁽¹²⁾ found that it cost more. An explanation for this finding is that cost data were only
282 obtainable for in-stock items, therefore causing a bias towards the FROs that had higher availability
283 and corresponding lower costs. Previous researchers have also encountered difficulties in comparing
284 the cost of food baskets^(9,13,21), with Beaulac et al.⁽¹⁴⁾ attributing the mixed findings to the low
285 methodological quality of the studies cost comparisons. As such, findings relating to HFB cost in the
286 present study, and indeed other food basket surveys, should be interpreted with caution. Despite this,
287 the findings from the present study suggest that the average cost of healthy food is comparable
288 between areas of contrasting deprivation, however clearly identifies considerable differences in the
289 cost of healthy food between convenience stores and supermarkets. Considering the higher proportion
290 of convenience stores in more-deprived areas, this suggests a social gradient in the cost of healthy
291 food.

292 The differences found in HFB availability between ward deprivation level were expected. On average,
293 availability was lower in the more-deprived areas compared to the less-deprived. Specifically,
294 wholegrain carbohydrates, fruit and vegetables, low fat dairy products, lean meats, oily fish and low
295 fat spread were less frequently stocked in the more-deprived areas (see **Table 1**). This finding accords

296 with previous research⁽⁹⁾, and is important because it suggests that residents of deprived areas could
297 struggle to eat healthily⁽³⁷⁾; thereby increasing their risk of NCDs⁽³⁸⁾. However, findings from a larger
298 study by White et al.⁽¹⁵⁾ contradict this, countering that healthy food availability is not
299 socioeconomically patterned, but is instead associated with store type. It is plausible that the findings
300 from this small scale local research are a result of the high prevalence of convenience stores in the
301 most-deprived area, which were found to have a lower availability of healthy foods compared to
302 supermarkets. This finding is undisputed in the literature⁽³⁸⁾, and in previous research has been
303 attributed to the lower demand for healthier and more perishable foods in deprived areas⁽¹⁵⁾.

304 It was interesting to find that the more-deprived areas contained more convenience stores and fewer
305 supermarkets than the less-deprived areas. This indicates that there is the potential for convenience
306 stores to influence the food retail environment in deprived communities, where it is suggested that
307 larger retailers avoid trading due to lower levels of disposable income in these areas⁽⁴⁰⁾. Despite
308 finding that convenience stores offered a lower provision of healthy foods, anecdotal evidence
309 collected found that some convenience store retailers were willing to stock healthier food items. One
310 ordered wholemeal bread upon customer request, whilst another stocked competitively priced, fresh
311 produce variety packs suitable for single household customers. These observations highlight the
312 potentially pivotal role that convenience store retailers could play in enhancing healthy food provision
313 in deprived areas, however indicates that some stores could benefit from additional education and
314 support to replicate this. As households in the more-deprived areas appeared most likely to depend
315 upon these stores, these promising anecdotal findings warrant further investigation. However, it
316 should be recognised that there is little incentive for improving the availability of healthy foods if
317 there is no demand⁽⁴¹⁾ and so this recommendation would need to be considered within the wider
318 determinants of food choice⁽⁴²⁾. Community and public health dietitians promote the importance of a
319 healthy diet within their local communities, and so would be appropriately placed to lead this
320 partnership with convenience store owners.

321 This study provides a unique insight into the food retail environment in areas of contrasting
322 deprivation in a South West UK coastal city. However, due to the specific locality of the four study
323 areas, the generalisability of the findings to other areas may be limited. Strengths include the thorough
324 identification and mapping of food retail outlets, in addition to the comprehensive assessment of HFB
325 availability, which further validates the previously developed HEISB tool⁽³⁰⁾. However,
326 methodological limitations are inherent in all research, and this study was no exception. Firstly, the
327 study's ecological and cross-sectional design was unable to differentiate cause and effect from simple
328 association⁽⁴³⁾. Secondly, the linear ArcGIS assessment of distance is somewhat over-simplistic. The
329 mapping of walking, driving and public transport routes would have generated the most

330 comprehensive depiction of the food retail environment, however was beyond the scope of the study.
331 Finally, the approach taken to compare the cost of HFB items has resulted in some being
332 disproportionately adjusted, which has consequently reduced the validity of these findings. Despite
333 the limitations highlighted, the findings from the present study will help to inform research regarding
334 the physical and social determinants of food choice; an area of key importance for public health
335 professionals.

336

337 **Recommendations and Future Work**

338 This exploratory research provides a better understanding of inequalities in healthy food provision,
339 and offer insight into why individuals from LSGs can fail to adhere to nutritional
340 recommendations⁽⁴⁴⁾. The largest scope to make a difference lies in areas where individuals are most
341 reliant upon their local food retail environment, which itself offers poor healthy food provision⁽¹³⁾.
342 This highlights an area where public health specialists, public health dietitians and policy makers may
343 have the largest impact. Interventions to increase healthy food provision could be achieved through
344 partnership-working with convenience store retailers, building on the previous successes of
345 Change4Life⁽⁴⁵⁾. Such initiatives could include the redesign of store layouts to ensure prominent
346 positioning of healthier foods, and introducing legislation to increase the display of healthier foods at
347 the point of sale and on in-store communications. Additionally, store owners could be encouraged to
348 increase their provision of less-perishable healthier food items⁽⁴⁶⁾. It would be interesting to develop
349 this research further, to explore the extent to which the access to, and cost and availability of healthy
350 food influences consumer dietary choice. This could complement research investigating both the
351 influence of the retail provision of unhealthy food⁽⁴⁷⁾, and the density and location of fast food outlets,
352 on dietary choice^(48,49).

353

354 **Conclusions**

355 Differences were found in the access to, and cost and availability of healthy foods in areas of
356 contrasting deprivation. These appeared related to FRO type rather than deprivation alone, with
357 convenience stores consistently demonstrating lower healthy food availability than supermarkets, and
358 at a higher cost. Future interventions to improve the access to, and cost and availability of healthy
359 food should concentrate upon the more-deprived communities, and partnership-working between
360 public health professionals and convenience stores could be pivotal in this process.

361

362 **Acknowledgements**

363 This research was supported by Plymouth University School of Health Professions. The authors are
364 grateful to Desley White for her support with statistical analysis and to Shaun Lewin, from Plymouth
365 University's School of Geography, Environmental and Earth Sciences, for his invaluable guidance
366 with Geographic Information Systems.

367

368 **Transparency declaration:** The lead author affirms that this manuscript is an honest, accurate, and
369 transparent account of the study being reported, that no important aspects of the study have been
370 omitted and that any discrepancies from the study as planned (and registered with) have been
371 explained. The reporting of this work is compliant with STROBE⁽⁵⁰⁾ guidelines.

372

373 **References**

- 374 1. Mulrooney HM & Bell J. Does the food retail environment reflect UK public health
375 recommendations for healthy eating? *Public Health* 2016 May;134:114-116.
- 376 2. Cabinet Office (2008) Food: an analysis of the issues.
377 http://webarchive.nationalarchives.gov.uk/+http://www.cabinetoffice.gov.uk/media/cabinetoffice/strategy/assets/food/food_analysis.pdf (accessed 24 November 2015).
- 378 3. Nelson M, Erens B, Bates B, Church S & Boshier T. (2007) *Low Income Diet and Nutrition*
379 *Survey*.
380 http://tna.europarchive.org/20110116113217/http://www.food.gov.uk/multimedia/pdfs/lidns_summary.pdf (accessed 2 December 2015).
- 381 4. Butland B, Jebb S, Kopelman P, McPherson K, Thomas S, Mardell J, et al. (2007) Foresight
382 Tackling Obesities: Future Choices – Project Report.
383 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/287937/07-1184x-tackling-obesities-future-choices-report.pdf (accessed 12 December 2015).
- 384 5. Roberts K, Cavill N, Hancock C & Rutter H. (2013) Social and economic inequalities in diet
385 and physical activity.
386 http://www.noo.org.uk/uploads/doc/vid_19253_Social_and_economic_inequalities_in_diet_and_physical_activity_04.11.13.pdf (accessed 12 December 2015).
- 387 6. Centres for Disease Control and Prevention (CDC) (2014) Healthier Food Retail: Beginning
388 the Assessment Process in Your State or Community.
389 <http://www.cdc.gov/obesity/downloads/hfrassessment.pdf> (accessed 12 December 2015).
- 390
391
392
393

- 394 7. Maslen C, Raffle A, Marriot S & Smith N. (2013) Food Poverty: What Does the Evidence
395 Tell Us? Bristol: Bristol City Council. [http://bristolfoodpolicycouncil.org/wp-](http://bristolfoodpolicycouncil.org/wp-content/uploads/2013/08/Food-Poverty-Report-July-2013-for-publication.pdf)
396 [content/uploads/2013/08/Food-Poverty-Report-July-2013-for-publication.pdf](http://bristolfoodpolicycouncil.org/wp-content/uploads/2013/08/Food-Poverty-Report-July-2013-for-publication.pdf) (accessed 12
397 December 2015).
- 398 8. Cavil N & Roberts K. (2011) Data sources: environmental influences on physical activity
399 and diet. [https://khub.net/c/document_library/get_file?uuid=68b8960e-4145-4ed2-b9f8-](https://khub.net/c/document_library/get_file?uuid=68b8960e-4145-4ed2-b9f8-1ce767f1d2ff&groupId=31798783)
400 [1ce767f1d2ff&groupId=31798783](https://khub.net/c/document_library/get_file?uuid=68b8960e-4145-4ed2-b9f8-1ce767f1d2ff&groupId=31798783) (accessed 10 October 2015).
- 401 9. Dawson J, Marshall D, Taylor M, Cummins S, Sparks L & Anderson A. (2008) Accessing
402 Healthy Food: A Sentinel Mapping Study of Healthy Food Retailing in Scotland.
403 [http://www.foodstandards.gov.scot/sites/default/files/655-1-1105_S04005_-](http://www.foodstandards.gov.scot/sites/default/files/655-1-1105_S04005_-_Final_report_part_1.pdf)
404 [_Final_report_part_1.pdf](http://www.foodstandards.gov.scot/sites/default/files/655-1-1105_S04005_-_Final_report_part_1.pdf) (accessed 19 December 2015).
- 405 10. Wong KC, Coveney J, Ward P, Muller R, Carter P, Verity F, et al. Availability, affordability
406 and quality of a healthy food basket in Adelaide, South Australia. *Nutr and Diet* 2011 Feb
407 24;68:8-14.
- 408 11. Gustafson A, Lewis S, Wilson C & Jilcott-Pitts S. Validation of food store environment
409 secondary data source and the role of neighborhood deprivation in Appalachia, Kentucky.
410 *BMC Public Health* 2012 Mar 11;12:688-700.
- 411 12. Cummins S. & MacIntyre S. A Systematic Study of an Urban Foodscape: The Price and
412 Availability of Food in Greater Glasgow. *Urban Stud* 2002 Oct 1:39:2115-2130.
- 413 13. White M, Bunting J, Williams L, Raybould S, Adamson A & Mathers J. (2004) Do ‘food
414 deserts’ exist? A multi-level, geographical analysis of the relationship between retail food
415 access, socio-economic position and dietary intake.
416 [http://s3.amazonaws.com/academia.edu.documents/37306342/fsareport.pdf?AWSAccessKe](http://s3.amazonaws.com/academia.edu.documents/37306342/fsareport.pdf?AWSAccessKeyId=AKIAIWOWYYGZ2Y53UL3A&Expires=1494521907&Signature=3T83DljDkmDRui)
417 [yId=AKIAIWOWYYGZ2Y53UL3A&Expires=1494521907&Signature=3T83DljDkmDRui](http://s3.amazonaws.com/academia.edu.documents/37306342/fsareport.pdf?AWSAccessKeyId=AKIAIWOWYYGZ2Y53UL3A&Expires=1494521907&Signature=3T83DljDkmDRui)
418 [cT03C%2FzhfuTiw%3D&response-content-](http://s3.amazonaws.com/academia.edu.documents/37306342/fsareport.pdf?AWSAccessKeyId=AKIAIWOWYYGZ2Y53UL3A&Expires=1494521907&Signature=3T83DljDkmDRui)
419 [disposition=inline%3B%20filename%3DDo food deserts exist A multi-level geog.pdf](http://s3.amazonaws.com/academia.edu.documents/37306342/fsareport.pdf?AWSAccessKeyId=AKIAIWOWYYGZ2Y53UL3A&Expires=1494521907&Signature=3T83DljDkmDRui)
420 (accessed 19 November 2015).
- 421 14. Beulac J, Kristjansson E & Cummins S. A Systematic Review of Food Deserts 1966-2007.
422 *Prev Chronic Dis* 2009 Jul;6.
- 423 15. Wrigley N, Warm D & Margetts B. (2003) Deprivation, diet, and food-retail access:
424 findings from the Leeds food deserts’ study.
425 <https://www.geog.soton.ac.uk/school/staff/profiles/nw/DDFRA.pdf> (accessed 10 November
426 2015).
- 427 16. Dowler E. Inequalities in diet and physical activity in Europe. *Public Health Nutr*
428 2001;4:701-09.

- 429 17. Acheson D. Independent Inquiry into Inequalities in Health. London: The Stationery Office;
430 1998.
- 431 18. Department for Transport (2015) *National Travel Survey: England 2014 (Statistical*
432 *Release)*.
433 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/457752/nts20
434 [14-01.pdf](https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/457752/nts20) (accessed 6 March 2017).
- 435 19. Caraher M, Lloyd S, Lawton J, Singh G, Horsley K, Mussa F, et al. A tale of two cities: A
436 study of access to food, lessons for public health practice. *J Health Educ* 2010 Jun;69:200-
437 210.
- 438 20. Pettinger C, Holdsworth M & Gerber M. ‘All under one roof?’ differences in food
439 availability and shopping patterns in Southern France and Central England. *Eur J Public*
440 *Health* 2007 Jun 16;1:109-114.
- 441 21. Bowyer S, Caraher M, Eilbert K & Carr-Hill R. Shopping for food: lessons from a London
442 borough. *Brit Food J* 2009;111:452-474.
- 443 22. Public Health (2015) Index of Multiple Deprivation (IMD) 2015 Plymouth Summary
444 Analysis. <https://www.plymouth.gov.uk/sites/default/files/IndexMultipleDepravation.pdf>
445 (accessed 12 November 2015).
- 446 23. The Department for Communities and Local Government (2015) The English Index of
447 Multiple Deprivation (IMD) 2015 – Guidance.
448 [https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/464430/Engli](https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/464430/English_Index_of_Multiple_Deprivation_2015_-_Guidance.pdf)
449 [sh_Index_of_Multiple_Deprivation_2015_-_Guidance.pdf](https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/464430/English_Index_of_Multiple_Deprivation_2015_-_Guidance.pdf) (accessed 15 March 2017).
- 450 24. Office for National Statistics (ONS) (2015) *Dataset: Ward Level Mid-Year Population*
451 *Estimates (experimental) Mid-2014: SAPE17DT8* [online]. Available at:
452 <http://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/population>
453 [estimates/datasets/wardlevelmidyearpopulationestimatesexperimental](http://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/population)
- 454 25. Institute of Grocery Distribution (2015) UK Grocery Retailing – How much is the UK
455 market worth? And which are its most important channels?
456 <http://www.igd.com/Research/Retail/UK-grocery-retailing/> (accessed 4 December 2015).
- 457 26. Lake AA, Burgoine T, Stamp E & Grieve R. The foodscape: classification and field
458 validation of secondary data sources across urban/rural and socio-economic classifications
459 in England. *Int J Behav Nutr Phys Act* 2012 Apr 2;9:37-49.
- 460 27. Her Majesty’s Stationary Office (2017) Trading hours for retailers: the law.
461 <https://www.gov.uk/trading-hours-for-retailers-the-law> (accessed 14 March 2017).

- 462 28. Esri (2014) ArcGIS (version 10.4) [computer software].
463 <http://www.esri.com/software/arcgis/arcgis-for-desktop> (accessed 13 December 2015).
- 464 29. Office for National Statistics (2013) Area Plymouth Car or Van Availability, 2011.
465 [http://neighbourhood.statistics.gov.uk/dissemination/LeadTableView.do?a=7&b=6275200&](http://neighbourhood.statistics.gov.uk/dissemination/LeadTableView.do?a=7&b=6275200&c=plymouth&d=13&e=61&g=6390905&i=1001x1003x1032x1004&m=0&r=1&s=1465823270922&enc=1&dsFamilyId=2511)
466 [c=plymouth&d=13&e=61&g=6390905&i=1001x1003x1032x1004&m=0&r=1&s=1465823](http://neighbourhood.statistics.gov.uk/dissemination/LeadTableView.do?a=7&b=6275200&c=plymouth&d=13&e=61&g=6390905&i=1001x1003x1032x1004&m=0&r=1&s=1465823270922&enc=1&dsFamilyId=2511)
467 [270922&enc=1&dsFamilyId=2511](http://neighbourhood.statistics.gov.uk/dissemination/LeadTableView.do?a=7&b=6275200&c=plymouth&d=13&e=61&g=6390905&i=1001x1003x1032x1004&m=0&r=1&s=1465823270922&enc=1&dsFamilyId=2511) (accessed 17 May 2016).
- 468 30. Anderson AS, Dewar J, Marshall D, Cummins S, Taylor M, Dawson J, et al. The
469 development of a healthy eating indicator shopping basket tool (HEISB) for use in food
470 access studies – identification of key food items. *Public Health Nutr* 2007 Jun 18;10:1440-
471 1447.
- 472 31. Public Health England (2016) Eatwell Guide.
473 [https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/528193/Eatw](https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/528193/Eatwell_guide_colour.pdf)
474 [ell_guide_colour.pdf](https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/528193/Eatwell_guide_colour.pdf) (accessed 24 June 2016).
- 475 32. Dinno A. Nonparametric pairwise multiple comparisons in independent groups using
476 Dunn’s test. *Stata J* 2015;15:292-300.
- 477 33. IBM (2013) *IBM SPSS Statistics for Windows* (version 22) [computer program]. Armonk,
478 NY: IBM Corporation.
- 479 34. Smith DM, Cummins S, Taylor M, Dawson J, Marshall D, Sparks L, et al. Neighbourhood
480 food environment and area deprivation: spatial accessibility to grocery stores selling fresh
481 fruit and vegetables in urban and rural settings. *Int J Epidemiol* 2010 Feb;39:277-284.
- 482 35. Institute of Grocery Distribution (2013) Online Grocery Shoppers.
483 <http://www.igd.com/Research/Shopper-Insight/Online-grocery-shoppers/> (accessed 23 June
484 2016).
- 485 36. Sauveplane-Stirling V, Crichton D, Tessier S, Parrett A & Garcia AL. The food retail
486 environment and its use in a deprived, urban area of Scotland. *Public Health* 2014
487 Apr;128:360-366.
- 488 37. Latetia VM, Diez Roux AV, Nettleton JA & Jacobs DR. Associations of the Local Food
489 Environment with Diet Quality – A Comparison of Assessments based on Surveys and
490 Geographic Information Systems. *Am J Epidemiol* 2008;176:917-924.
- 491 38. World Health Organisation (2015) Noncommunicable diseases.
492 <http://www.who.int/mediacentre/factsheets/fs355/en/> (accessed 23 November 2015).
- 493 39. Black C, Ntani G, Inskip H, Cooper C, Cummins S, Moon G, et al. (2014) Measuring the
494 healthfulness of food retail stores: variations by store type and neighbourhood deprivation. *Int*
495 *J Behav Nutr Phys Act* 2014 May 23;11:69-80.

- 496 40. Donkin AJM, Dowler EA, Stevenson SJ & Turner SA. Mapping access to food at a local level.
497 Brit Food J, 1999;101:554-564.
- 498 41. MSIF and NHS Lothian. Food for Thought: Midlothian Community Food Survey 2002-2003.
499 Dalkeith: NHS Lothian; 2003.
- 500 42. European Food Information Council (2006) The Determinants of Food Choice.
501 <http://www.eufic.org/article/en/expid/review-food-choice/> (accessed 5 December 2015).
- 502 43. Mann CJ. Observational Research Methods. Research Design II: Cohort, Cross Sectional and
503 Case-Control Studies. J Emerg Med 2003;20:54-60.
- 504 44. Nelson, M., Erens, B., Bates, B., Church, S. and Boshier, T. (2007) *Low income diet and*
505 *nutrition survey: Summary of key findings* (pdf).
506 [http://tna.europarchive.org/20110116113217/http://www.food.gov.uk/multimedia/pdfs/lidns](http://tna.europarchive.org/20110116113217/http://www.food.gov.uk/multimedia/pdfs/lidns_summary.pdf)
507 [summary.pdf](http://tna.europarchive.org/20110116113217/http://www.food.gov.uk/multimedia/pdfs/lidns_summary.pdf) (accessed 2 December 2015).
- 508 45. Department of Health (2010) Change4Life Convenience Stores Evaluation Report.
509 [https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/215984/dh_1](https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/215984/dh_120801.pdf)
510 [20801.pdf](https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/215984/dh_120801.pdf) (accessed 24 June 2016).
- 511 46. Adams J, Halligan J, Watson DB, Ryan V, Penn L, Adamson AJ, et al. The Change4Life
512 Convenience Store Programme to Increase Retail Access to Fresh Fruit and Vegetables: A
513 Mixed Methods Process Evaluation. PLOS One 2012 Jun 27;7:e39431.
- 514 47. Jones NRV, Conklin AI, Suhrcke M & Monsivais P. The Growing Price Gap between More
515 and Less Healthy Foods: Analysis of a Novel Longitudinal UK Dataset. PLOS One 2014
516 Oct 8;9:e109343.
- 517 48. Burgione T. Associations between exposure to takeaway food outlets, takeaway food
518 consumption, and body weight in Cambridgeshire, UK: population based, cross sectional
519 study. BMJ 2014 Mar 13;348:1464-1474.
- 520 49. Public Health England (2017) Health matters: Obesity and the food environment.
521 [https://www.gov.uk/government/publications/health-matters-obesity-and-the-food-](https://www.gov.uk/government/publications/health-matters-obesity-and-the-food-environment/health-matters-obesity-and-the-food-environment--2)
522 [environment/health-matters-obesity-and-the-food-environment--2](https://www.gov.uk/government/publications/health-matters-obesity-and-the-food-environment/health-matters-obesity-and-the-food-environment--2) (accessed 11 May 2017).
- 523 50. STROBE (N.D.) STROBE Statement – Checklist of items that should be included in reports
524 of cross-sectional studies. [http://www.strobe-](http://www.strobe-statement.org/fileadmin/Strobe/uploads/checklists/STROBE_checklist_v4_cross-sectional.pdf)
525 [statement.org/fileadmin/Strobe/uploads/checklists/STROBE_checklist_v4_cross-](http://www.strobe-statement.org/fileadmin/Strobe/uploads/checklists/STROBE_checklist_v4_cross-sectional.pdf)
526 [sectional.pdf](http://www.strobe-statement.org/fileadmin/Strobe/uploads/checklists/STROBE_checklist_v4_cross-sectional.pdf) (Accessed 3 December 2016).

527

528