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Deprivation and healthy food access, cost and availability: a cross-sectional study

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Keywords
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Abstract

Background: Food access, cost and availability have been identified as determinants of dietary choice. It has been suggested that these are socio-economically patterned; however, the evidence is inconclusive. The present study investigated whether differences exist with respect to healthy food access, cost and availability between areas of contrasting deprivation.
Methods: An ecological, cross-sectional study was conducted in two of the most and two of the least deprived wards in Plymouth. Food retail outlets (FROs) (n = 38) were identified and mapped using Geographic Information Systems to assess 'physical access', by foot, to food retail provision. Healthy food basket (HFB) surveys were conducted (n = 32) to compare the cost and availability of 28 healthy food items between the more and less deprived areas.
Results: Areas of poor access to food retail provision were identified in both study areas, with a higher number of households in the more-deprived areas being affected than in the less-deprived areas, after accounting for car ownership levels. Median [IQR] HFB availability was lower in more-deprived than the less-deprived areas (48%, [39-71%] vs. 75%, [68-82%]; P=0.003), and in convenience stores than supermarkets (54%, [43-72%] vs. 78%, [72-96%]; P=0.001). Descriptive summaries revealed negligible differences in total median HFB cost between the more-deprived and less-deprived areas (£55.97 versus £55.94) and a larger cost difference between convenience stores and supermarkets (£62.39 versus £44.25).
Conclusions: Differences were found with respect to healthy food access, cost and availability in areas of contrasting deprivation. These appeared to be related to FRO type rather than deprivation alone.

Introduction

The 'food environment' has been implicated as a critical determinant of food choice [1]. If UK diets matched nutritional guidelines, almost 70 000 premature deaths from chronic noncommunicable diseases could be prevented annually [2]. This is particularly pertinent to low socio-economic groups (LSGs) as a result of the documented social gradient in the nutritional quality of the diet, with studies reporting that those on the lowest incomes consume more salt, sugar and saturated fat, and less fruit and vegetables [3]. However, dietary choice is multifaceted and complex because of influences from a range of biological and societal factors [4]. Increasingly, research has focused upon the influence of the food environment on dietary choice, suggesting that food access, cost and availability may be important determinants of the nutritional quality of the diet [5].

Food access refers to physical access to food retail provision [5] and is dependent upon geographical location and resources such as transport accessibility [4]. The Geographic Information System (GIS) is considered useful for

assessing food retail access [6] as a result of its capacity to map and spatially analyse data [7]. Availability refers to the types of food retail outlets (FROs) in a geographical area, as well as the foods that they sell [8]. Previous research has measured the availability and cost of healthy food items using Healthy Food Basket (HFB) surveys [9,10], which have been found to have sufficient sensitivity to discriminate well between stores [9].

It has been suggested that food access, cost and availability are socio-economically patterned, with research from the USA finding that lower income areas have lower access to healthy foods [11]. Specifically, it was observed that the FROs in these areas offered lower healthy food availability, at the same time as also charging higher prices [12,13]. Areas where it is difficult to purchase healthy food items at a reasonable price are referred to as 'Food Deserts'[13]. The existence of Food Deserts is widely accepted in the USA [14], however, is vigorously debated in the literature elsewhere [13,15].

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

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

Materials and methods

Study design

This exploratory ecological cross-sectional study investigated healthy food retail access in areas of contrasting deprivation in Plymouth; a South West UK coastal city. FROs were identified using primary and secondary data sources, and were mapped using GIS to determine areas of poor physical access, by foot, to food retail provision. Healthy food availability and cost were assessed and compared using a HFB survey. All data were collected during 1 week in May 2016, aiming to minimise seasonable variations in food availability and cost.

Food retail outlets

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

Food retail outlets were consecutively sampled from an extensive list of all identified FROs in the four wards, generated using secondary data sources including Local Authority databases, Google Maps and Yell.com, as well as websites of major food retailers and symbol groups (e.g. Premier). In line with other studies, 500 m was considered to be a reasonable distance to travel to FROs by foot [21] and thus FROs within 500 m of the ward boundaries were included in the study because residents on ward boundary edges would still have access to these FROs[19]. Included FROs were superstores (25–60 000 square feet), supermarkets (3–25 000 square feet) and convenience stores (<3000 square feet), as defined in the UK by the Institute of Grocery Distribution (IGD) [25]. All other FROs were excluded as a result of the observation that food shopping in England is most commonly completed 'under one roof' [20].

To validate the secondary data sources used, all identified FROs were verified visually or by telephone contact because primary data collection in the form of field work has been identified as the 'gold standard' for verifying the food environment [26]. As a result of some identified discrepancies between the classification of FROs on Google and the retailers' own websites, the researchers re-classified FROs in accordance with the IGD definitions. The definition of a convenience store is well-established [27]; however, because of practical limitations, store managers were relied upon to verify the classification between supermarket and superstore. From this, the 39 verified

FROs were identified and invited to participate in the research. Consent to conduct in-store data collection was sought by postal letter and nonrespondents were followed-up in person.

ARCGIS, version 10.4 [28] was used to map the spatial coordinates of all 39 verified FROs, and to create 500-m geographical buffer zones around each. Areas within the ward which fell outside of these zones were considered to have poor physical access, by foot, to food retail provision. Census datasets relating to car ownership were also incorporated at the LSOA level [29]. This was to enable a visual appraisal of the percentage of households without car availability, which are located in areas identified to have poor physical access, by foot, to food retail provision.

Healthy food basket survey

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

Table 1 Differences in availability of healthy food basket items (%) by deprivation level and food retail outlet type

	Deprivation level		Food retail outlet type	
Food item (n = 28)	High (n = 20) Stocked, n (%)*	Low (n = 12) Stocked, n (%)*	Convenience store (n = 25) Stocked, n (%)*	Supermarket (n = 7) Stocked, 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)

*Category consists of groups: 'in-stock', 'out of stock, awaiting delivery', not stocked but first substitute available', not stocked, but second substitute available'.

Statistical analysis

Data were inputted into EXCEL (Microsoft Corp., Redmond, WA, USA) in duplicate, and cross-checked for consistency by another member of the research team to improve the inter-rater reliability. All data analysis was conducted by deprivation level (more-deprived, less-deprived), by FRO type (convenience store, supermarket) and by FRO subtype (more-deprived convenience stores, more-deprived supermarkets, less-deprived convenience stores, less-deprived supermarkets) categories. No superstores were identified in the study areas.

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

A Mann–Whitney U-test was conducted to determine differences in percentage HFB availability between deprivation level and FRO type. A Kruskal–Wallis analysis of variance was also conducted to determine differences in percentage HFB availability between FRO subtype. Dunn's pairwise comparison with Bonferroni adjustment provided post-hoc analysis [32]. Statistical analysis was

conducted using EXCEL (Microsoft Corp.) and SPSS, version 22.0 (IBM Corp., Armonk, NY, USA) [33]. $P \leq 0.05$ was considered statistically significant.

Ethical considerations

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

Results

Food retail outlets

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

Access

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

Healthy food basket survey

Descriptive summaries revealed negligible differences in median HFB cost between the more-deprived and the less-deprived areas (£55.97 versus £55.44). However, a larger cost difference was found between convenience stores and supermarkets (£62.39 versus £44.25). Subgroup

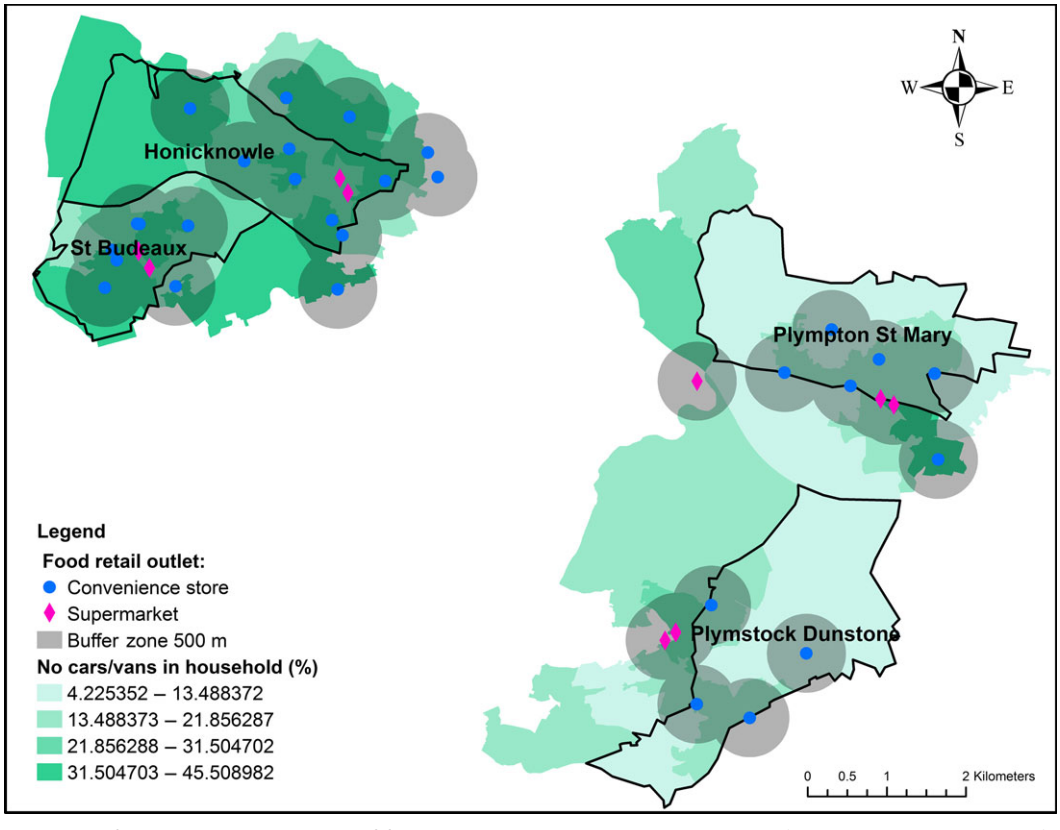

Figure 1 Geographic Information Systems mapping of food retail outlets in the more-deprived areas (Honicknowle and St Budeaux) and the less-deprived areas (Plympton St Mary and Plymstock Dunstone). Areas outside of the geographical buffer zones indicate poor physical access, by foot, to food retail provision,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

analysis found that the median HFB cost was lower in both convenience stores and supermarkets in the more-deprived areas than in convenience stores and supermarkets in the less-deprived areas (£60.15 and £42.30 versus £63.60 and £45.48, respectively).

Across the 32 FROs surveyed, four (13%) stocked all 28 HFB items, whereas 21 (66%) stocked at least half of the HFB. Median [IQR] HFB availability was lower in the more-deprived areas compared to the less-deprived (48% [39-71%] vs. 75% [68-82%]; U=195.000, P=0.003), and in convenience stores compared to supermarkets (54% [43-72%] vs. 78% [72-96%]; U=153.500, P=0.001). These data are reported in Table 1. Median HFB availability differed by FRO subtype ($H^2 = 16.272$, $P = 0.001$), with the largest difference identified between convenience stores in the more-deprived areas and supermarkets in the less-deprived areas ($P = 0.018$). Differences in availability were also found between convenience stores in the more-deprived areas and convenience stores in the less-deprived areas ($P = 0.044$), as well as between convenience stores in the more-deprived areas and supermarkets in the less-deprived areas ($P = 0.047$).

Discussion

The present exploratory study investigated whether deprivation level affects healthy food access, cost and availability. Areas of poor physical access, by foot, to food retail provision were identified in both study areas. However, within these areas of poor access, local data show that more households in the more-deprived areas did not have access to a car or van compared households to in the less-deprived areas [29] (Fig. 1). Previous research has failed to demonstrate socio-economic patterning regarding the access to healthy food retail provision[34]; however, those living in the more-deprived areas are less likely to have access to a car [27]. Despite their use of taxis [13] and online food shopping [35], individuals without car access are significantly more likely to travel home from food shopping by foot [36]. Therefore, they are likely to be particularly susceptible to changes in the local food retail environment regarding the provision of healthy food. Interestingly, the more-deprived areas contained more convenience stores and fewer supermarkets than the less-deprived areas [9]. Because less individuals in the more-deprived areas had access to a car or van [29], this suggests a heavier reliance upon convenience stores for those living in more-deprived areas.

In terms of the cost of healthy food, it was expected that convenience stores would charge more on average for the full HFB, and this is supported by the existing literature [13]. Therefore, it was surprising that negligible differences were found in the cost of healthy food between the more and the less-deprived areas. Although this aligns with findings obtained in the study by White *et al.* [13], it contrasts with other studies reported in the literature. Dawson *et al.* [9] found that healthy food cost less in less deprived areas, whereas Cummins and McIntyre [12] found that it cost more. An explanation for this finding is that cost data were only obtainable for in-stock items, therefore causing a bias towards the FROs that had higher availability and corresponding lower costs. Previous studies have also encountered difficulties in comparing the cost of food baskets [9,13,21], with Beaulac *et al.* [14] attributing the mixed findings to the low methodological quality of the studies cost comparisons. As such, findings relating to HFB cost in the present study, and indeed other food basket surveys, should be interpreted with caution. Despite this, the findings from the present study suggest that the average cost of healthy food is comparable between areas of contrasting deprivation; however, it clearly identifies considerable differences in the cost of healthy food between convenience stores and supermarkets. Considering the higher proportion of convenience stores in more-deprived areas, this suggests a social gradient in the cost of healthy food.

The differences found in HFB availability between ward deprivation level were expected. On average, availability was lower in the more-deprived areas compared to the less-deprived areas. Specifically, wholegrain carbohydrates, fruit and vegetables, low fat dairy products, lean meats, oily fish and low fat spread were less frequently stocked in the more-deprived areas (Table 1). This finding is in accordance with previous research [9] and is important because it suggests that residents of deprived areas could struggle to eat healthily [37], thereby increasing their risk of noncommunicable diseases [38]. However, findings from a larger study by White *et al.*[15] contradict this, countering that healthy food availability is not socio-economically patterned but, instead, is associated with store type. It is plausible that the findings from this small scale local research are a result of the high prevalence of convenience stores in the most-deprived area, which were found to have a lower availability of healthy foods compared to supermarkets. This finding is undisputed in the literature [39] and, in previous research, has been attributed to the lower demand for healthier and more perishable foods in deprived areas [15].

It was interesting to find that the more-deprived areas contained more convenience stores and fewer supermarkets than the less-deprived areas. This indicates that there is the potential for convenience stores to influence the food retail environment in deprived communities, where it is suggested that larger retailers avoid trading as a result of lower levels of disposable income in these areas [40]. Despite finding that convenience stores offered a lower

provision of healthy foods, anecdotal evidence collected found that some convenience store retailers were willing to stock healthier food items. One store ordered wholemeal bread upon customer request, whereas another stocked competitively priced, fresh produce variety packs suitable for single household customers. These observations highlight the potentially pivotal role that convenience store retailers could play in enhancing healthy food provision in deprived areas, although they also indicate that some stores could benefit from additional education and support to replicate this. Because households in the more-deprived areas appeared most likely to depend upon these stores, these promising anecdotal findings warrant further investigation. However, it should be recognised that there is little incentive for improving the availability of healthy foods if there is no demand [41] and so this recommendation would need to be considered within the wider determinants of food choice [42]. Community and public health dietitians promote the importance of a healthy diet within their local communities, and so they would be appropriately placed to lead this partnership with convenience store owners.

The present study provides a unique insight into the food retail environment in areas of contrasting deprivation in a South West UK coastal city. However, because of the specific locality of the four study areas, the generalisability of the findings to other areas may be limited. Strengths include the thorough identification and mapping of FROs, in addition to the comprehensive assessment of HFB availability, which further validates the previously developed HEISB tool [30]. However, methodological limitations are inherent in all research, and the present study was no exception. First, the ecological and cross-sectional design of the study was unable to differentiate cause and effect from simple association [43]. Second, the linear ARCGIS assessment of distance is somewhat oversimplistic. Mapping of the walking, driving and public transport routes would have generated the most comprehensive depiction of the food retail environment, although this was beyond the scope of the present study. Finally, the approach taken to compare the cost of HFB items has resulted in some being disproportionately adjusted, consequently reducing the validity of these findings. Despite the highlighted limitations, the findings from the present study will help to inform research regarding the physical and social determinants of food choice, which is an area of key importance for public health professionals.

Recommendations and future work

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

Conclusions

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

Transparency declaration

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

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Conflict of interests, source of funding and authorship

The authors declare that they have no conflicts ofinterest.
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SW, MMcG-S, BB and BW conducted the data collection. SW, MMcG-S, BB and BW conducted the statistical analysis. SW led the journal write up. MMcG-S, BB and BW conducted the proofreading. MMcG-S and CP assisted with the journal write up. CP provided supervision and feedback throughout the study.

References

1. Mulrooney HM & Bell J (2016) Does the food retail environment reflect UK public health recommendations for healthy eating? *Public Health* **134**, 114–116.
2. Cabinet Office (2008) Food: An Analysis of the Issues. Available at: http://webarchive.nationalarchives.gov.uk/+/http:/www.cabinetoffice.gov.uk/media/cabinetoffice/strategy/assets/food/food_analysis.pdf (accessed November 2015).
3. Nelson M, Erens B, Bates B *et al.* (2007) Low Income Diet and Nutrition Survey. Available at: http://tna.europarchive.org/20110116113217/http://www.food.gov.uk/multimedia/pdfs/lidnssummary.pdf (accessed December 2015).
4. Butland B, Jebb S, Kopelman P *et al.* (2007) Foresight Tackling Obesities: Future Choices – Project Report. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/287937/07-1184x-tackling-obesities-future-choices-report.pdf (accessed December 2015).
5. Roberts K, Cavill N, Hancock C *et al.* (2013) Social and economic inequalities in diet and physical activity. Available at: http://www.noo.org.uk/uploads/doc/vid_19253_Social_and_economic_inequalities_in_diet_and_physical_activity_04.11.13.pdf (accessed December 2015).
6. Centres for Disease Control and Prevention (CDC) (2014) Healthier Food Retail: Beginning the Assessment Process in Your State or Community. Available at: http://www.cdc.gov/obesity/downloads/hfrassessment.pdf (accessed December 2015).
7. Maslen C, Raffle A, Marriot S *et al.* (2013) Food Poverty: What Does the Evidence Tell Us? Bristol: Bristol City Council. Available at: http://bristolfoodpolicycouncil.org/wp-content/uploads/2013/08/Food-Poverty-Report-July-2013-for-publication.pdf (accessed December 2015).
8. Cavil N & Roberts K (2011) Data Sources: Environmental Influences On Physical Activity And Diet. Available at: https://khub.net/c/document_library/get_file?uuid=68b8960e-4145-4ed2-b9f8-1ce767f1d2ff&groupId=31798783 (accessed October 2015).
9. Dawson J, Marshall D, Taylor M *et al.* (2008) Accessing Healthy Food: A Sentinel Mapping Study of Healthy Food Retailing in Scotland. Available at: http://www.foodstandards.gov.scot/sites/default/files/655-1-1105_S04005_-_Final_report_part_1.pdf (accessed December 2015).
10. Wong KC, Coveney J, Ward P *et al.* (2011) Availability, affordability and quality of a healthy food basket in Adelaide, South Australia. *Nutr Diet* **24**, 8–14.
11. Gustafson A, Lewis S, Wilson C *et al.* (2012) Validation of food store environment secondary data source and the role of neighborhood deprivation in Appalachia, Kentucky. *BMC Public Health* **11**, 688–700.
12. Cummins S & MacIntyre S (2002) A systematic study of an urban foodscape: the price and availability of food in greater glasgow. *Urban Stud* **1**, 2115–2130.
13. White M, Bunting J, Williams L *et al.* (2004) Do 'Food Deserts' Exist? A Multi-Level, Geographical Analysis of the Relationship Between Retail Food Access, Socio-Economic Position and Dietary Intake. Available at: http://s3.amazonaws.com/academia.edu.documents/37306342/fsareport.pdf?AWSAccessKeyId=AKIAIWOWYYGZ2Y53UL3A&Expires=1494521907&Signature=3T83DljDkmDRuicT03C%2FzhfuTiw%3D&response-content-disposition=inline%3B%20filename%3DDo_food_deserts_exist_A_multi-level_geog.pdf (accessed November 2015).
14. Beaulac J, Kristjansson E & Cummins S (2009) A systematic review of food deserts 1966-2007. *Prev Chronic Dis* **6**, A105.
15. Wrigley N, Warm D & Margetts B (2003) Deprivation, Diet, and Food-Retail Access: Findings from the Leeds Food Deserts' Study. Available at: https://www.geog.soton.ac.uk/school/staff/profiles/nw/DDFRA.pdf (accessed November 2015).
16. Dowler E (2001) Inequalities in diet and physical activity in Europe. *Public Health Nutr* **4**, 701–709.
17. Acheson D (1998) *Independent Inquiry into Inequalities in Health*. London: The Stationery Office.
18. Department for Transport (2015) National Travel Survey: England 2014 (Statistical Release). Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/457752/nts2014-01.pdf (accessed March 2017).
19. Caraher M, Lloyd S, Lawton J *et al.* (2010) A tale of two cities: a study of access to food, lessons for public health practice. *J Health Educ* **69**, 200–210.

20. Pettinger C, Holdsworth M & Gerber M (2007) 'All under one roof?' differences in food availability and shopping patterns in Southern France and Central England. *Eur J Public Health* **16**, 109–114.
21. Bowyer S, Caraher M, Eilbert K *et al.* (2009) Shopping for food: lessons from a London borough. *Br Food J* **111**, 452–474.
22. Public Health (2015) Index of Multiple Deprivation (IMD) 2015 Plymouth Summary Analysis. Available at: https://www.plymouth.gov.uk/sites/default/files/IndexMultipleDepravation.pdf (accessed November 2015).
23. The Department for Communities and Local Government (2015) The English Index of Multiple Deprivation (IMD) 2015 – Guidance. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/464430/English_Index_of_Multiple_Deprivation_2015_-_Guidance.pdf (accessed March 2017).
24. Office for National Statistics (ONS) (2015) Dataset: Ward Level Mid-Year Population Estimates (experimental) Mid-2014: SAPE17DT8 [online]. Available at: http://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationestimates/datasets/wardlevelmidyearpopulationestimatesexperimental (accessed 10 May 2017).
25. Institute of Grocery Distribution (2015) UK Grocery Retailing – How much is the UK market worth? And which are its most important channels? Available at: http://www.igd.com/Research/Retail/UK-grocery-retailing/ (accessed December 2015).
26. Lake AA, Burgoine T, Stamp E *et al.* (2012) The foodscape: classification and field validation of secondary data sources across urban/rural and socio-economic classifications in England. *Int J Behav Nutr Phys Act* **2**, 37–49.
27. Her Majesty's Stationary Office (2017) Trading Hours for Retailers: The Law. Available at: https://www.gov.uk/trading-hours-for-retailers-the-law (accessed March 2017).
28. Esri (2014) ArcGIS (version 10.4) [computer software]. Available at: http://www.esri.com/software/arcgis/arcgis-for-desktop (accessed December 2015).
29. Office for National Statistics (2013) Area Plymouth Car or Van Availability, 2011. Available at: 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 May 2016).
30. Anderson AS, Dewar J, Marshall D *et al.* (2007) The development of a healthy eating indicator shopping basket tool (HEISB) for use in food access studies – identification of key food items. *Public Health Nutr* **18**, 1440–1447.
31. Public Health England (2016) Eatwell Guide. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/528193/Eatwell_guide_colour.pdf (accessed June 2016).
32. Dinno A (2015) Nonparametric pairwise multiple comparisons in independent groups using Dunn's test. *Stata J* **15**, 292–300.
33. IBM (2013) *IBM SPSS Statistics for Windows, version 22 [computer program]*. Armonk, NY: IBM Corporation.
34. Smith DM, Cummins S, Taylor M *et al.* (2010) Neighbourhood food environment and area deprivation: spatial accessibility to grocery stores selling fresh fruit and vegetables in urban and rural settings. *Int J Epidemiol* **39**, 277–284.
35. Institute of Grocery Distribution (2013) Online Grocery Shoppers. Available at: http://www.igd.com/Research/Shopper-Insight/Online-grocery-shoppers/ (accessed June 2016).
36. Sauveplane-Stirling V, Crichton D, Tessier S *et al.* (2014) The food retail environment and its use in a deprived, urban area of Scotland. *Public Health* **128**, 360–366.
37. Latetia VM, Diez Roux AV, Nettleton JA *et al.* (2008) Associations of the local food environment with diet quality – a comparison of assessments based on surveys and geographic information systems. *Am J Epidemiol* **176**, 917–924.
38. World Health Organisation (2015) Noncommunicable Diseases. Available at: http://www.who.int/mediacentre/factsheets/fs355/en/ (accessed November 2015).
39. Black C, Ntani G, Inkskip H *et al.* (2014) Measuring the healthfulness of food retail stores: variations by store type and neighbourhood deprivation. *Int J Behav Nutr Phys Act* **11**, 69–80.
40. Donkin AJM, Dowler EA, Stevenson SJ *et al.* (1999) Mapping access to food at a local level. *Br Food J* **101**, 554–564.
41. MSIF and NHS Lothian (2003) *Food for Thought: Midlothian Community Food Survey 2002–2003*. Dalkeith: NHS Lothian.
42. European Food Information Council (2006) The Determinants of Food Choice. Available at: http://www.eufic.org/article/en/expid/review-food-choice/ (accessed December 2015).
43. Mann CJ (2003) Observational research methods. research design II: cohort, cross sectional and case-control studies. *J Emerg Med* **20**, 54–60.
44. Nelson M, Erens B, Bates B *et al.* (2007) Low Income Diet and Nutrition Survey: Summary of Key Findings (pdf). Available at: http://tna.europarchive.org/20110116113217/http://www.food.gov.uk/multimedia/pdfs/lidnssummary.pdf (accessed December 2015).
45. Department of Health (2010) Change4Life Convenience Stores Evaluation Report. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/215984/dh_120801.pdf (accessed June 2016).

46. Adams J, Halligan J, Watson DB *et al.* (2012) The Change4Life convenience store programme to increase retail access to fresh fruit and vegetables: a mixed methods process evaluation. *PLoS ONE* **27**, e39431.
47. Jones NRV, Conklin AI, Suhrcke M *et al.* (2014) The growing price gap between more and less healthy foods: analysis of a novel longitudinal UK dataset. *PLoS ONE* **8**, e109343.
48. Burgione T (2014) Associations between exposure to takeaway food outlets, takeaway food consumption, and body weight in Cambridgeshire, UK: population based, cross sectional study. *BMJ* **13**, 1464–1474.
49. Public Health England (2017) Health Matters: Obesity and the Food Environment. Available at: https://www.gov.uk/government/publications/health-matters-obesity-and-the-food-environment/health-matters-obesity-and-the-food-environment–2 (accessed May 2017).
50. STROBE (N.D.) STROBE Statement – Checklist of Items That Should be Included in Reports of Cross-Sectional Studies. Available at: http://www.strobe-statement.org/fileadmin/Strobe/uploads/checklists/STROBE_checklist_v4_cross-sectional.pdf (accessed December 2016).

