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## The UK food environment: a systematic review of domains, methodologies and outcomes

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### 1 Abstract

Understanding food environments is crucial for developing policies and interventions to enhance 2 3 the healthfulness and sustainability of UK diets. We systematically reviewed published scientific 4 research to answer two research questions. First, what types and domains of the food 5 environment have been assessed in the UK using what methodologies? Domains included 6 availability, affordability, promotion, product characteristics/quality, convenience, and sustainability. Second, what outcomes have been assessed in relation to food environments? 7 Outcomes were classified as descriptive (describing the food environment), dietary intake, and 8 9 health. Articles published between January 2000 and December 2024 were identified by searching seven databases: CAB Abstracts, CINAHL, EMBASE, Global Health, PubMed, 10 Scopus, and Web of Science. A total of 31,457 articles were identified, 3,418 full texts were 11 reviewed, and 286 articles were included. Another 26 articles were included after screening the 12 references of articles identified in the database search. Thus, data were extracted from a total of 13 14 312 articles. The most common domain studied was availability (n=100, 32%), followed by product characteristics/quality (n=94, 30%) and promotion (n=33, 10%). There was a paucity of 15 research on the domains of sustainability (n=19, 6%) and affordability (n=16, 5%), with no 16 17 articles on the domain of convenience. Only 49 articles (16%) evaluated more than one domain. Most articles were descriptive (n=206, 66%); 64 (20%) evaluated the association of the food 18 19 environment with dietary intake and 42 (13%) evaluated the association with health, nearly all 20 with obesity. The current literature on the food environment in the UK focusses largely on 21 availability in the food retail space. More research is needed to understand how different 22 domains of the food environment interact to influence dietary intake and health.

- 23 **Registry number for systematic reviews:** The protocol was registered with PROSPERO (ID:
- 24 CRD42022306066) on 8 February 2022.
- 25 **Keywords:** Food environment, UK, Food retail, Fast food, Food packaging, Food safety, Access
- to food, Sustainable diets

## Introduction

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Obesity has surpassed smoking as the leading contributor to death since 2014 in the UK (1). The prevalence of obesity across the UK is high, with 32% of adults in Scotland having obesity (2), and 22% and 26% of adults in Wales (3) and England (4), respectively. By 2035, the prevalence of obesity in adults is predicted to increase by 5 percentage points in Scotland, 8 percentage points in England and 11 percentage points in Wales (5). Similarly worrying trends have been observed in children. From 2019-20 to 2020-21, the prevalence of obesity in children 4-5 years old increased from 9.9% to 14.4% and in children 10-11 years old, it increased from 21.0% to 25.5% (6). Unhealthy diets underlie these worrying trends in obesity. The latest National Diet and Nutrition Survey (2023) found that consumption of fruits and vegetables is well below the 5-A-Day recommendation and mean intake of free sugars exceeds the maximum recommendation in all age groups (7). While many continue to place the onus of change on individuals, it is increasingly recognized that food environments that encourage the consumption of unhealthy foods are critical drivers of food choice (8). The food environment is the interface between people and the wider food system. It encompasses all places where people access food, including retailers, restaurants, pubs/bars, cafes/coffee shops, takeaways, mobile food vans, schools, universities, workplaces, and charities as well as deliveries from these places (9). The UK food environment has mirrored trends in unhealthy diets and obesity, with most evidence derived from the built environment. From 1980 to 2000, a study in North East England found a 79% increase in the total number of food outlets with a particularly marked increase in 'foods for consumption away from home' outlets, which increased by 259% compared to a 16% increase in 'household shopping' outlets (10). Similar increases in availability of take-aways and grocers/convenience

stores were reported around secondary schools in East London from 2001 to 2005 (11). In 2022,
there were an estimated 42,341 fast food outlets across the UK (12). Today, particularly
following the COVID-19 pandemic, the way in which people in the UK procure food has
diversified, with an increasing number of people ordering food online and using delivery services
(e.g., Just Eat, Deliveroo, Uber Eats) (13). According to the Food Standards Agency's "Food and
You 2" survey of 5,812 UK participants, conducted between April and July 2024, 75% of
respondents reported shopping at large supermarkets while 19% said they used delivery apps
such as Just Eat, Deliveroo, or Uber Eats at least once a week (14). When asked about their
preferences for ordering food or drinks online, 60% of respondents reported that they preferred
to order from the websites of a restaurant, takeaway or café.

To date, there has not been a comprehensive review of the literature on UK food environments. Previous, multi-country or US-specific reviews do exist, however, and have focused on the retail food environment (15-17) or specific population subgroups, such as school children (18-20), or specific health outcomes, such as obesity (21-23). There is also some recent interest in understanding the digital food environment given the widespread use of grocery and food delivery services in the UK, but this remains a largely unexplored area of research (24, 25).

The aim of this systematic review was to identify and narratively summarize recent evidence regarding the UK food environment and to identify research gaps. The first research question was "what types and domains of food environments have been assessed using which methodologies?" The second was "which outcomes have been assessed in relation to food environments, including descriptive (describing the food environment), dietary intake, and health". Further, "how these outcomes have been stratified by area deprivation, education, gender, income, ethnicity, and age". For all research questions, we explored how the number of

73	articles differed by geography (e.g., UK-wide versus England, Scotland, Wales or Northern
74	Ireland).
75	This systematic review provides an evidence-based understanding of food environment
76	research in the UK, identifying geographical disparities and research gaps, and highlighting a
77	need for bridging various food environment domains to foster cohesive changes and ultimately
78	create healthier and more sustainable food systems.
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## Methods

The protocol was registered with PROSPERO (ID: CRD42022306066) on 8 February 2022. As this was not deemed human subjects' research, it was exempt from institutional ethics committee review.

## Framework and definitions

The review was grounded in the Downs et al. 2020 framework wherein six domains of food environments are defined, including availability, affordability, promotion, product characteristics/quality, convenience, and sustainability (**Table 1**) (26). Whilst this framework proposes three types of food environments – built, cultivated, and natural – in the context of the UK, the built food environment is predominant (26).

### Search strategy

The search strategy was developed by reviewing protocols on the food environment published in PROSPERO. Seven electronic databases were searched from inception through December 2024: CAB Abstracts, CINAHL, EMBASE, Global Health, PubMed, Scopus, and Web of Science. Searches included key words for domains of the food environment (e.g., "food access\*" "supermarket" etc.) AND key words for the geographic area of interest (e.g., "United Kingdom" "UK" etc.). The search terms and results for each database are given in Supplementary Table 1. Searches were duplicated by a second reviewer to check for accuracy. Additional articles were identified after reviewing the references of articles meeting inclusion criteria.

## Study selection

The eligibility criteria were as follows: research articles that measured at least one domain of the food environment (availability, affordability, promotion, product

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characteristics/quality, convenience, or sustainability); conducted in the UK (England, Wales, Scotland, or Northern Ireland); original research using quantitative or mixed methods with no restrictions on study design; and published from 2000 to December 2024 in English. Only studies published since 2000 were included to better inform local decision-making (policymakers prioritize recent evidence) and subsequent research to address gaps in our understanding of UK food environments. The exclusion criteria were articles on food choices, personal factors such as taste, cultural preferences, knowledge about food, dietary intakes or behaviours without measuring food environments; qualitative articles; articles published in a language other than English; narrative reviews, systematic reviews, opinions, editorials, commentaries, or letters not reporting original research; and articles conducted outside the UK. If the research was conducted outside the UK but measured food environments in the UK, it was included. Articles on the home food environment were excluded. These included articles on marketing such as the impact of TV advertising or time spent on TV viewing in the home/ personal food environment. This review only included articles on advertising in the built food environment – i.e., in-store promotions, packaging of foods, etc.

Search results were imported into Covidence systematic review software (Veritas Health Innovation, Melbourne, Australia) for screening. The search yielded 31,457 articles, of which 13,753 were duplicates (**Figure 1**). DK and MVD independently screened titles and abstracts for eligibility, resulting in the exclusion of 14,286 records. Any discrepancies were resolved through discussion with LMJ. Interrater reliability was assessed using percent agreement (94.2%) and Cohen's kappa ( $\kappa$ =0.83), indicating substantial agreement between reviewers. Full texts of 3,418 articles were sought for retreival, of which full text of 14 articles was not available. The full texts of 3,404 articles were then reviewed by DK and MVD. Of these, 3,092 were excluded and 286

- were included. Another 26 were included after screening the references of these 286 articles.
- Thus, the total number of articles included was 312.

#### Data extraction

Data from all eligible articles were extracted into an Excel database. The Excel database was developed by DK with input from LMJ and tested on a subset of included articles, making iterative revisions to the database as necessary. DK and MVD extracted data, with uncertainties discussed and resolved with LMJ. Data were extracted on:

- Article characteristics. This included the last name of the first author, year of publication, year of data collection, country study was conducted in (UK-wide, England, Wales, Scotland, or Northern Ireland), study design, sample population, sample size, and source of funding.
  - Type of food environment evaluated. Lytle's (27) categorization of the food environment was adapted to define seven types of built food environments: (1) food store environment (including grocery stores, supermarkets, convenience stores, snack bars, specialty food stores, and farmers' markets), (2) school food environment (including cafeterias, vending machines, and snack shops in day care settings, schools, colleges, and universities and the areas around them), (3) worksite food environment (including cafeterias, vending machines, and snack shops in worksites), (4) neighborhood food environment (all places to procure food within a physical region outside residential address), (5) macro food environment (national and regional food supply), (6) public facility food environment (including cafeterias, vending machines, and snack shops in recreation centers, health care facilities, and other public venues), and (7) restaurant food environment.

- Domains of food environment evaluated (**Table 1**). This included availability, affordability, promotion, product characteristics/quality, convenience, and sustainability (26). For the purposes of this systematic review, articles on food choices, personal factors such as taste, cultural preferences and knowledge about food were not considered part of the food environment.
- Methodology used to assess the domains of the food environment. Any methodology was considered acceptable, including but not limited to instruments such as checklists, interviews or questionnaires; geographic analysis; sales data, nutrient and menu analysis.
   Lytle (27) methodologies and instruments were adapted to define 12 types of methodologies, detailed in Table 2. For intervention studies conducted in the food environments, details on type of intervention were extracted.
- Outcome assessment. This included information on the type of outcome (descriptive, diet, or health), outcome assessment method, and any stratification by area deprivation, education, gender, income, ethnicity and age.

Details on variables extracted from observational and intervention studies are listed in **Supplementary Table 2**. This systematic review assessed attributes such as the number of articles measuring the food environment across geographies (i.e., Wales, England, Scotland, Northern Ireland and UK wide); the number of articles assessing the type of measure (e.g., geographical analysis, menu analysis, nutrient fact panel analysis, etc.); and the environment in which the measurement tool was used (e.g., food store, restaurant, school, etc.). No formal risk of bias assessment was done. Details for all included articles in the systematic review (n=312) are listed in **Supplementary Table 3**.

## Results

171	Key characteristics of articles included in the systematic review are presented in <b>Table 3</b> .
172	Most articles were from England [n=120, 38% (10, 11, 21, 24, 28-143)], followed by UK wide
173	articles [n=87, 28%], Scotland [n=27, 9% (144-170)], Northern Ireland [n=9, 3% (171-179)], and
174	Wales [n=10, 3% (180-189)]. There were 7 articles from Great Britain (190-196) and 21 (6%)
175	multi-country studies (197-217). We further categorized the number of articles at the regional
176	level in each country, showing clear preferences and paucity of food environment research in
177	some areas (Figure 2). In England, most articles were from London (n=27, 26%) and Yorkshire
178	and Humber (n=18, 15%); in Scotland they were from Glasgow (n=12, 43%) and in Wales from
179	Cardiff (n=6, 67%). Within each region, details of urban or rural areas were not provided. Only
180	19 articles evaluated urban/rural differences (42, 45, 50, 75, 90, 95, 106, 126, 131, 138, 155, 157,
181	162, 167, 168, 171, 175, 179, 191). After the search and analysis of articles had been conducted,
182	one article retraction was published (218).
183	Over the past decade, research on food environments has expanded significantly, with
184	58% of articles (n=184) published after 2015 and 26% (n=81) after 2020. However, only 5%
185	[n=16, (24, 87, 90, 94, 111, 197, 213, 219-227)] of these articles noted data collection occurring
186	post-2020. Most articles (n=184, 59%) did not focus on any population group such as children or
187	the elderly but on measuring food environment features. Most articles were cross-sectional
188	(n=242, 78%), followed by longitudinal analysis [n=31, 10% (10, 11, 41, 45, 61, 72, 74, 77, 87,
189	90, 100, 138, 159, 186, 207, 219, 223, 224, 228-240)], intervention studies [n= 17, 5% (28, 43,
190	62, 63, 69, 86, 114, 115, 123, 160, 172, 208, 225, 241-244)], case studies [n= 10, 3% (31, 67,
191	153, 181-183, 185, 245, 246)] and 2% each (n=6) were randomized controlled trials (111, 112,
192	127, 128, 130, 220) and modelling studies (57, 133, 195, 247-249).

Since this review focused on multiple domains of the food environment, the sample size ranged 193 from 115 to 42,838 people; 3 to 8,864 stores; 101 to 68,153 food samples or products; 8 to 194 195 2,255,404 meals, and 3 to 6,781 areas. On tabulation of articles based on type of food studied, 31% (n=97) of the articles focused on type of food outlets instead of focusing on any particular 196 food or food group (10, 11, 31-33, 36, 38-42, 45-47, 49-52, 55, 57, 59, 60, 65-67, 72-79, 82, 87-197 198 92, 94, 95, 100-102, 106-108, 117-119, 122, 123, 126, 131, 141-143, 145, 148-151, 155, 157, 162, 169, 177, 182-184, 190, 191, 194, 199, 200, 210, 212, 213, 223, 228, 234, 246, 250-263). 199 200 These were followed by articles on ready-to-eat foods [n=34, 11% (63, 83, 103, 109, 113, 114, 201 135, 139, 158, 159, 170, 172, 185-187, 189, 192, 201, 206, 211, 264-277)] and articles on meals served at schools, restaurants, or workplaces [n=32, 10% (28, 35, 43, 58, 62, 68-70, 84, 85, 97, 202 111-113, 127-129, 132, 140, 160, 181, 205, 220, 224, 278-285)]. Of 312 articles, 210 (67%) 203 stated their source of funding. Among these, 161 articles (52%) that received government 204 funding, 33 (10%) articles were funded by charitable NGOs, foundations, or professional 205 206 societies, 9 (3%) articles were funded by intergovermental bodies like World Health Organisation, and 5 articles (2%) received funding from private charities (74, 108, 114, 118, 207 286). One article noted joint funding from government and industry (184), while another stated 208 209 joint funding from government and a private charity (217). A total of 63 articles (20%) did not mention their source of funding and 39 articles (12%) did not receive any funding. 210 Types of food environments 211 212 Articles on food store environments were the most common [n=208, 67% (30, 35, 50, 56, 61, 73, 79-81, 107, 114, 133, 135, 141, 143, 144, 159, 161, 178, 190, 195, 200, 202, 209, 215, 213 214 218, 225, 226, 230, 231, 237, 240, 242, 244, 249-251, 256, 261, 274, 278, 287-293)] [**Figure 3**]. 215 These included articles on the nutrient content (29, 34, 53, 116, 124, 139, 140, 166, 192, 206,

207, 214, 216, 232, 236, 238, 264, 266, 267, 269-271, 275, 277, 285, 286, 294-304) and 216 microbial content (93, 163, 168, 172-174, 176, 203, 204, 208, 305) of foods sold in UK food 217 218 stores, availability of healthy foods (40, 59, 130, 146, 147, 156, 175, 182, 183, 229, 235, 242, 306) and access to food stores (37, 38, 49, 57, 66, 106, 110, 137, 138, 142, 150, 152, 153, 165, 219 171, 191, 194, 256, 307). The next most prevalent food environment was restaurant food 220 221 environments [n=52, 16% (28, 43, 51, 89, 92, 102, 125, 151, 213, 233, 246, 253, 265, 308)] which included articles on nutrient content (70, 84, 111, 118, 205, 212, 220, 223, 257, 259, 260, 222 262, 263, 279, 281) or microbiological quality (103, 280, 309-312) of meals served at fast food 223 or full service restaurants. Thirty-six articles evaluated different aspects of neighborhood (10, 31, 224 39, 48, 82, 94, 119, 120, 136, 252, 313, 314) such as 20-minute neighborhood (162) or out of 225 home access in deprived neighborhoods (55, 78, 86, 95, 100, 101, 126, 131, 148, 157, 167, 182, 226 193, 247, 254, 315). Articles assessing nutritional content of school meals (68, 71, 132, 181, 243, 227 316) or vending machines (109) at schools were categorized under school food environments 228 [n=28, 9% (11, 32, 67, 72, 75, 111, 117, 121, 122, 134, 145, 149, 177, 187, 210, 241, 283)]. 229 Twelve articles assessed the online food environment: eight UK-wide articles (25, 219, 221, 222, 230 227, 245, 317), three from England (44, 87, 90) and one multi-country study (198). There were 231 232 15 articles on hospitals and other public venues categorised as public facility food environment (58, 60, 63, 65, 83, 104, 105, 113, 123, 129, 169, 185, 188, 282, 318); 8 articles on worksite food 233 234 environment (62, 85, 97, 111, 127, 128, 160, 224) and 19 articles on macro food environment 235 assessing impact of food policies (42, 52, 158, 164, 211, 217, 234, 248, 255, 276, 289, 319-326). There were 22 (7%) articles that evaluated two types of food environments (33, 45, 47, 73, 180, 236 237 189, 268), of which 13 were on food store and restaurant food environment (46, 77, 78, 88, 105,

- 186, 258, 327). For example, articles evaluating microbial quality of food samples collected from food stores and fast-food restaurants (103, 328).
- There were no articles on natural food environments (both wild and cultivated). All of the above were classified as the built food environment.

## Domains and methodologies

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- 243 The most common domain studied was availability [n=100, 32% (10, 11, 24, 31-33, 38,
- 39, 41, 42, 45-52, 55, 57, 60, 65-67, 72, 73, 75-79, 81-83, 86-92, 94, 95, 100-102, 106, 108, 111-
- 245 113, 117, 119, 121, 122, 126, 131, 133, 134, 136-138, 142, 143, 145, 147-151, 153, 155, 162,
- 246 167, 175, 177, 182-184, 191, 193, 194, 199, 210, 213, 228, 234, 242, 250, 252-256, 276, 306,
- 308, 315, 329, 330)], followed closely by product characteristics/quality [n=94, 30% (29, 34, 53,
- 248 56, 58, 70, 84, 85, 93, 97, 103-105, 107, 109, 120, 124, 129, 139, 144, 163, 168, 170, 172-174,
- 249 176, 178, 185-189, 192, 201, 203-208, 212, 216, 219, 223, 232, 236, 238, 257, 259, 260, 262-
- 250 264, 266-271, 273-275, 277-283, 285, 286, 290, 294-301, 305, 310-312, 314, 317, 328, 331-
- 251 334)] and promotion [n=33, 10% (25, 61, 64, 74, 81, 114, 125, 127, 128, 130, 141, 158, 159,
- 252 161, 169, 180, 190, 197, 200, 211, 215, 226, 227, 240-244, 249, 261, 272, 291, 335)] (**Figure 4**).
- 253 There was a paucity of research on the domains of sustainability [n=19, 6% (43, 68, 69, 202,
- 254 224, 245-248, 251, 265, 284, 289, 319, 321, 322, 324, 336, 337)] and affordability [n=16, 5%]
- 255 (37, 80, 110, 164, 165, 179, 195, 209, 230, 231, 233, 235, 237, 287, 307, 323)]. There were no
- articles on the domain of convenience. Under the domain availability, most articles focused on
- assessing density or proximity of food outlets (41, 228). Others focused on the type of foods
- available in food stores (86, 112, 123). These included fresh fruits and vegetables, and ready-to-
- eat and unhealthy foods (e.g., soft drinks, chips, confectionary, etc.). Under the domain product
- 260 characteristics/quality, most articles assessed nutrient content [e.g., fatty acids, trans fat, sodium,

sugar, etc.] (139, 238, 273) or microbial pathogens in food store or restaurant food environments		
(311, 312). Articles on marketing and nutritional claims on food packaging were covered under		
the promotion domain (197, 272, 335), while those on food prices were most common under the		
affordability domain (195, 320). Lastly, articles on the environmental impact of food were		
covered under sustainability (336).		
There were 50 articles (16%) that evaluated more than one domain, most common were		
articles evaluating availability and affordability [n=15, (37, 40, 44, 54, 59, 98, 99, 146, 156, 157,		
160, 171, 182, 184, 258)], and articles assessing affordability and product characteristics/ quality		
[n=10, (30, 36, 37, 140, 220, 222, 229, 288, 320, 325)]. One article evaluated all domains except		
convenience. It was an 11-country study to benchmark the implementation of recommended		
nutrition policies by national governments using the Healthy Food Environment Policy Index		
(217). The most studied domain in England, Scotland and Northern Ireland was availability,		
while in Wales and UK-wide articles it was quality. More details can be found in		
Supplementary Table 3.		
There was a clear preferred methodology to measure each domain (Figure 5). However,		
because several articles assessed multiple domains, the categories are not mutually exclusive and		

There was a clear preferred methodology to measure each domain (**Figure 5**). However, because several articles assessed multiple domains, the categories are not mutually exclusive and therefore have been counted more than once. Geographic analysis was the most common methodology used to assess availability, applied in 84% (n=108) of articles on availability (308). This was followed by market basket surveys [n=10, 9%] (155) policy analysis [n=5, 5%] (117) and physical measurements [n=2, 2%] (199). Assessing food purchase patterns using sales/cashier receipts [n=23, 58%] (36), market basket surveys [n=16, 40%] (37) and policy analysis [n=1, 2%] (217)were the most used methodologies to assess the affordability domain. To measure promotion, 7 (24%) articles used sales/ purchase analysis (64) and policy analysis

(138) each, 6 articles (21%) used nutrient information available on the package called nutrient fact panel analysis (335) and market basket surveys (74) each, and 3 articles (10%) used physical measurements (169). Nutrient fact panel analysis [n=44, 39%] (201), contaminant analysis [n=33, 29%] (331), articles on food samples tested in a laboratory, called nutrient analysis [n=21,18%] (85), menu analysis [n=12, 10%] (262), market basket surveys (198) and policy analysis [n=2, 2%] (283) each were methodologies to evaluate the domain on product characteristics/ quality.

Lastly, to measure sustainability, ecological footprint analysis (n=14, 70%), policy analysis [n=5, 25%] (336) and sales/ purchase analysis [n=1, 5%] (224) were used. It is important to note that within ecological footprint analysis, multiple methodologies were used, such as life cycle analysis (284, 319), reduction in livestock product supply (248), and Water Footprint Impact Indicator estimated as scarcity weighted liters per portion and global hectares per annum (71). This highlights the multi-faceted nature of sustainability definitions and data sources.

#### **Outcomes**

Overall, most articles (n=206, 66%) were descriptive and did not assess any associations between the food environment, 64 (20%) assessed associations with dietary intake (11, 28, 33, 34, 49, 58, 70, 84-86, 99, 107, 109, 112, 116, 118, 120, 125, 127, 128, 132, 136, 139, 140, 145, 170, 212, 223, 229, 230, 232, 235, 236, 238, 242, 260, 263, 264, 266, 267, 269-275, 277, 278, 282, 285, 294-296, 298, 299, 301, 303, 314, 317, 325, 333, 335), and 42 (13%) articles assessed associations with health (39, 45, 47, 48, 50-52, 55, 65, 66, 72, 73, 75-77, 80-82, 94, 97, 102, 126, 133, 134, 137, 138, 142, 194, 195, 199, 219, 228, 234, 247, 252, 254, 255, 276, 308, 315, 322) (**Table 4**). Of the articles assessing health associations, all focused on obesity and the impact of

307	food outlet proximity or density on body mass index, except four articles: one analyzed links
308	with type 2 diabetes (276), two focused on cardiovascular disease and cancer (248, 254) and
309	another with type 2 diabetes, cardiovascular disease and cancer (247). No country-wise
310	differences were observed: descriptive articles were most common across all countries (Table 4).
311	Most of the articles with outcomes did not present stratified analyses (n=233, 75%); 64
312	(20%) articles did stratified analysis by a single variable (32, 37, 38, 40, 44, 55, 59, 60, 66, 67,
313	74-78, 82, 86, 87, 89, 90, 92, 95, 98, 100, 106, 114, 117, 131, 137, 138, 142, 147, 149-151, 154-
314	158, 161, 162, 165-167, 171, 182-184, 190, 192, 193, 213, 231, 234, 242, 243, 250, 252, 253,
315	313, 315, 319, 329) and 15 (5%) articles conducted stratified analysis using two or more
316	variables (33, 42, 73, 81, 89, 101, 122, 126, 133, 134, 225, 254, 255, 289, 321) ( <b>Supplementary</b>
317	Table 4). Area deprivation was the most common variable for stratification, for example, articles
318	comparing food outlet density in the least and most deprived neighborhoods (37, 87).

## **Discussion**

A comprehensive understanding of the UK food environment requires interdisciplinary research involving public health experts, nutritionists, behavioral scientists, geographers, and complex systems scientists, among others. However, this systematic review found that most research to date has involved only one or a few aspects of the food environment. While more than 250 articles have been published on the UK food environment over the past two decades, most were on a single domain (availability) and in a single type of food environment, food store. Moreover, obesity was the only health outcome studied extensively. Given recent diversification of the way in which people in the UK procure food, with an increasing number of people ordering food and using delivery services (13), and the cost-of-living crisis, climate crisis, EU exit, and other disruptions to the UK food supply, more interdisciplinary work is needed to explore how interactions across multiple domains impact dietary intake and health.

Further, despite evidence that convenience is a key driver of food consumption behavior in the UK (13) as well as the impact of food systems on climate change (338), this systematic review identified little research on these food environment domains: convenience and sustainability. According to the Food and Agriculture Organization, the processing, packaging, and transport of food have overtaken agriculture as the largest contributor to food-related greenhouse gas emissions in many high-income countries (339). Similarly, evidence suggests that time spent on home food preparation is an indicator of healthy diets (340) and lack of time is a leading barrier to adopting dietary recommendations (341), yet there were no articles identified under the domain of convenience. Consumer interest in sustainability and convenience are megatrends of the fast-food sector in the UK, evident with nearly half of UK adults buying more

locally sourced food and expecting food businesses to play a role in climate change (12). There is also a continued high demand for home food delivery post pandemic (12).

Only about one-fifth of articles identified in this review evaluated more than one domain of the food environment. Valuable insights have come from the few articles identified in this review that looked at multiple domains. For example, the Healthy Food Environment Policy Index, which aimed to assess the extent of implementation of recommended food environment policies by governments, provided a holistic view of the UK's food environment (217). It also identified priority actions to meet implementation gaps (217). Another article evaluating multiple domains identified in this review looked at what dietary changes are required to shift the UK population to diets that meet dietary recommendations for health, have lower greenhouse gas emissions, and are affordable for different income groups (313). To fully comprehend the impact of the food environment on human and planetary health, research is needed that evaluates multiple domains and how these domains interact with each other to influence food choice. For example, ready-to-eat foods are convenient, but are often less affordable, less healthy, come in plastic packaging, and require refrigeration, which impacts their sustainability (342).

With regards to the type of food environment studied, food store environments have been the most researched food environment type by far. More than half of the articles (67%) in this review were on the food store environment, followed by restaurants (16%), neighborhood food environments (11%), and school food environments (9%). These findings differ slightly from Lytle's systematic review of articles measuring the food environment published between 2007 and 2015, which found that 73% of articles measured the food store environment, 50% measured restaurants, and 15% measured schools (percents do not add to 100 because some articles measured both) (27). The emphasis on food store environments is appropriate given that 71% of

expenditures on food and non-alcoholic drinks in the UK is at stores (with the remaining 29% of expenditures eaten out) (343). However, there is an increasing need to evaluate the online food environments given the rise in take-aways and deliveries (344), supermarket home delivery, and other forms of home delivery (e.g., vegetable boxes, Hello Fresh and Amazon Fresh) (13). We found only seven articles (2%) that assessed the online food environment in this systematic review, focusing on either availability or labelling of food items in the retail food environment.

About 70% of articles identified in this review were descriptive with no association with dietary intake or health outcomes. Among the few articles that evaluated associations with health outcomes, all but four evaluated the association with obesity. The other four studied type 2 diabetes, cardiovascular disease, and cancer. This is expected as obesity is the leading risk factor for mortality in the UK (1), but other diet-related diseases such as type 2 diabetes, hypertension and heart disease should also be explored.

This systematic review is not without limitations. Firstly, we did not include search terms for food banks or charity shops, which are an increasingly important source of food during the cost-of-living crisis (345). We also did not include search terms explicitly related to cultivated or natural food environments (for example, community gardens), and therefore may have missed literature on these types of food environments. Secondly, grey literature such as third sector or government reports may have been missed. We tried to overcome this by searching seven databases and reviewing the reference list for all included articles but cannot guarantee that a relevant report was not missed. Third, the search terms used for 'convenience' may have contributed to the lack of studies identified for this domain. Future work should consider expanding the search terms and definition to include the time cost of preparing and consuming

food as well as personal motivation to plan / prepare meals, availability of ingredients and cooking equipment in the home, and access to transport to procure ingredients.

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This study advances understanding of the knowledge gaps that must be filled in order to design evidence-based policies to improve the healthfulness and sustainability of UK diets. At the same time, there is enough evidence for governments to act in order to improve local food environments to achieve healthy diet and weight goals (346). A recently published review of systematic reviews on the effectiveness of food environment policies in improving population diets found that food environment policies targeting the availability of foods in retail and food establishments, food provision in school settings, product reformulation, and the size of portions/packages are effective (347). There are many recent examples of the UK and devolved government actions to improve the food environment. For example, the ban of single-use plastics in England that was initiated from October 2023 (348) and initiatives to reduce food waste (349, 350) have the potential to improve the sustainability of food environments. Regulations on the promotion of foods and beverages high in fat, sugar and salt in England (351) and under consideration in Scotland (352) and Wales (353) have the potential to improve the healthfulness of food environments across the UK. A data visualization tool has also been developed to help local authorities explore their food environments (354). There is a need for a comprehensive review of policies across the UK, including non-food policies and monitoring of the impact of these policies on dietary intake, health and food environments. The better we understand the food environment, the easier it will be to create interventions that bring about a positive change in public health and planetary health.

To summarize, the current literature on the food environment in the UK focusses almost exclusively on availability in the food retail space. Though several recent government initiatives

aim to improve the healthfulness of food environments in the UK, more research is needed to
understand how different domains of the food environment interact to influence dietary intake
and health. Moreover, the types of food environments evaluated need to be expanded to include
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Data sharing: Extracted data is publicly and freely available without restriction at
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### 1375 Figure Legends

- 1376 **Figure 1.** PRISMA flow diagram for systematic review of food environments in the UK.
- 1377 **Figure 2.** Geographic distribution of number of articles by country in a systematic review of
- the UK food environment (n=312).
- 1379 **Figure 3.** Number of articles by type of food environment and country in a systematic review
- of the UK food environment. Categories are non-exclusive, i.e., articles that evaluated more
- than one type of food environment are counted more than once.
- Figure 4. Number of articles by domain of food environment in a systematic review of the UK
- food environment (n=312). The colored boxes represent the domains while the number on the bar
- represents the number of articles in the domains. The presence of multiple, colored boxes signifies more
- than one domain.

John Marie President

1386	Figure 5. Type of methodology under each domain of food environment in a systematic
1387	review of the UK food environment. Categories are non-exclusive, i.e., articles that used
1388	more than one methodology are counted more than once.
1389	Tables
1390	

Domain	Definition	
Availability	The presence of a particular food item in a specific physical space or	
	range	
Affordability	The cost of food items in comparison to other foods or to income	
	benchmarks (e.g., % of median income or % of poverty line)	
Promotion	Factors that impact on the attractiveness of foods like packaging,	
	labelling (including traffic light labelling) and placement in the store	
Product characteristics	Features such as food packaging, nutrient and microbial content of	
(Quality)	foods, processing of foods and freshness of foods	
Convenience	Time spent procuring, cooking and consuming foods	
Sustainability	The environmental and social impact of food consumption	

<b>Table 2.</b> Definitions of methodologies to measure the food environment		
Name	Definition	Example
Geographic analysis Menu	Analysis of data collected for a specific geographic area. This includes, for example, counts of the number of food stores or restaurants; and distance to the nearest food stores or restaurants  Collects standardized	Number of fast-food restaurants and convenience stores around home and school neighborhoods for 3,089 adolescents (121)
analysis	information from menus	content of menu items from 100 restaurants in the UK (262)
Market basket survey	Collects standardized information (on food characteristics, price, product placement, availability or including pictures of products) for a pre-defined list of foods via direct observation of the food environment or online. These foods may be based on foods frequently consumed by the population or foods of public health concern. Typically used in food store environments	Using a healthy food basket to determine availability and pricing of key items from shops in two localities (98)
Sales/ purchase analysis	Use data from sales, cashier receipts, and annotated receipts to assess food purchasing patterns	An experimental study to examine the effect on vegetarian sales by increasing the proportion of vegetarian options available in university cafeterias (69)
Nutrient fact panel analysis	The nutrient content of foods available in a food environment is analyzed using existing information provided on the product itself (e.g., nutrient fact panel or claims on labeling) or using a nutrient database	Comparion of the Nutrition Information Panel content, serving size and package size of children's ready-to-eat breakfast cereals in 5 countries (201).
Nutrient analysis	Food samples are collected from a food outlet and analyzed in a laboratory for specific nutrients	Trans fatty acid content of 62 processed food (pizza, garlic bread, breakfast cereals, quiche, fat spreads,

		fish and meat products,
		chips, savoury snacks,
		confectionery and ice
		cream) purchased from
		supermarkets, independent
		retailers and takeaway
		outlets (333)
Contaminant	Food samples are collected	Assessment of the
	Food samples are collected from a food outlet and analyzed	
analysis	•	microbiological safety of
	in a laboratory for contaminants	salad vegetables and sauces
	such as pesticides or pathogens	from kebab take-away
		restaurants in the UK (312)
Physical	Data collected via physical	Association of supermarket
measurements	measurements of stores such as	size (measured as total aisle
	aisle length, shelf length, and	length) and national obesity
	placement	prevalence in England (199)
Ecological	Life cycle assessments	Environmental Impact
footprint	determine the environmental	Score of sandwiches and
analysis	impact of foods available in	beverages available in 18
	food environments	university-owned food
		outlets (71)
Policy	Articles analyzing policies or	
analysis	recommendations that impact	Banning the promotion of
	on the domains of food	foods high in fat, sugar and
	environments such as taxes or	salt in Scotland has the
	food labelling requirements	potential to reduce the number
	rood lacening requirements	of calories, sugar, saturated
		fats and sodium for most food
	<b>3</b>	groups (165)
Food supply	Uses national level data such as	Modelling study to shift
analysis	food prices, food availability, or	current diets to diets that
	food consumption	meet dietary
		recommendations for
		health, have lower
		greenhouse gas emissions
		and are affordable for
		different income groups
		(313)
		(0.20)

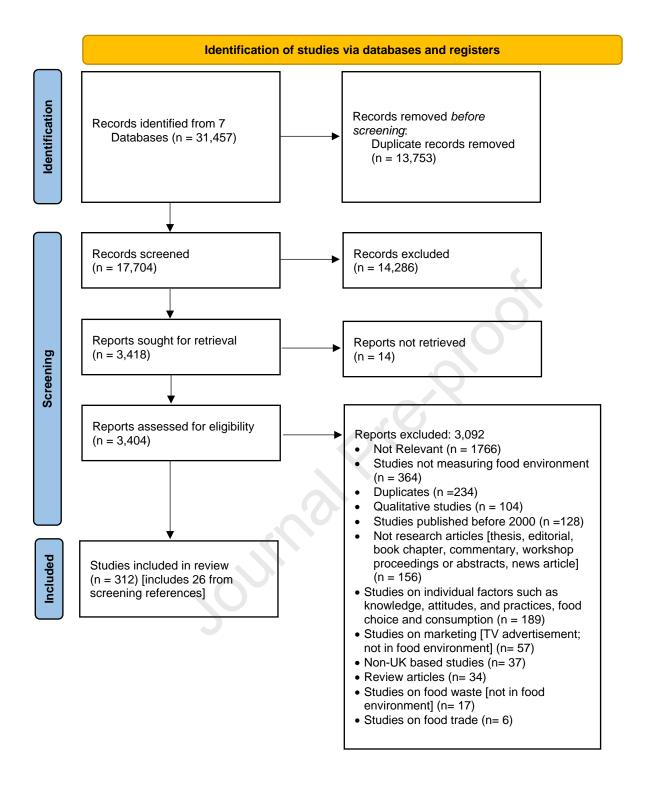
<b>Table 3.</b> Key characteristics of articles included in	the systematic review of the UK	
food environment (n=312)		
Characteristic	n (%) or range	
Geography		
UK-wide	87 (28)	
England	120 (38)	
Scotland	27 (9)	
Northern Ireland	9 (3)	
Wales	10 (3)	
Great Britain	7 (2)	
Coastal waters of UK	1 (1)	
Scotland and England	3 (1)	
Multi-country	21 (7)	
Not able to assign	27 (8)	
Location		
Not specified	262 (84)	
Both rural and urban	18 (6)	
Only urban	32 (10)	
Year of publication		
2000-2005	23 (7)	
2006-2010	30 (10)	
2011-2015	75 (24)	
2016-2020	103 (33)	
Beyond 2020	81 (26)	
Year of data collection		
Not reported	76 (24)	
≤2000	12 (4)	
2001-2005	18 (6)	
2006-2010	47 (15)	
2011-2015	55 (18)	
2016-2020	88 (28)	

Beyond 2020	16 (5)
Population	
Infant	7 (2)
Children	35 (11)
Adolescents	26 (9)
Adults	57 (18)
Elderly	3 (1)
N/A	184 (59)
Study design	C.
Cross-sectional	242 (78)
Longitudinal	31 (10)
Case study	10 (3)
Modelling	6 (2)
Randomized controlled trial	6 (2)
Intervention	17 (5)
Sample size	
People	115 to 42,838
Store	3 to 8,864
Food samples or products	101 to 68,153
Meals	8 to 2,255,404
Areas	3 to 6,781
Type of food(s) evaluated	
Unhealthy foods (fast foods, sweets, cakes,	26 (9)
pastries, etc.)	
Healthy foods (salads, whole grain cereals, dried	11 (4)
fruits, nuts etc.)	
Mix of healthy and unhealthy foods (salads and	31 (10)
confectionary)	
Fruits and vegetables	18 (6)
Meat and seafood	17 (5)
Milk and milk products	13 (4)
Beverages (including alcoholic beverages)	9 (3)

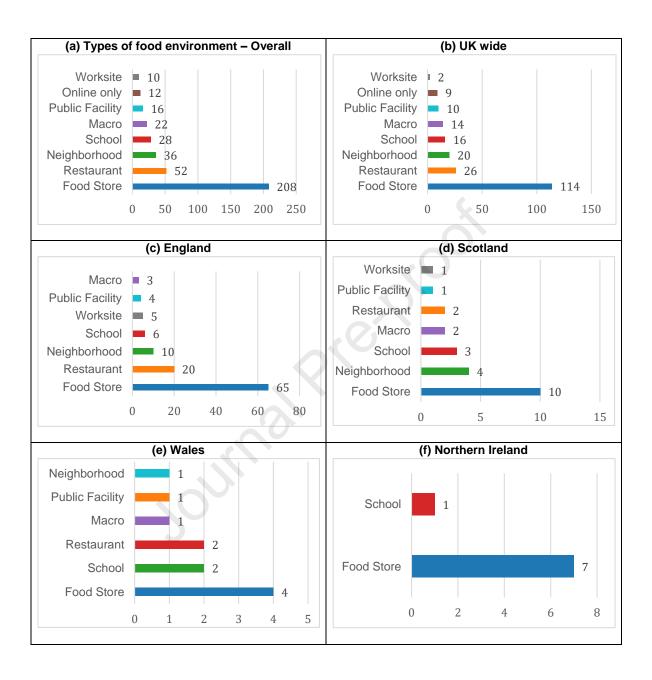
Bread	5 (2)
Baby/ infant food	3 (1)
Articles on multiple food groups	9 (3)
Ready-to-eat	34 (11)
Special foods- e.g., low protein, gluten free, meat	7 (2)
alternatives	
Meals (meals served at schools, restaurants,	32 (10)
workplaces, etc.)	
Food outlets	97 (31)
Source of Funding	
Government	161 (52)
Charitable NGOs, Foundations, or Professional	33 (10)
societies	(O)
Intergovermental bodies	9 (3)
Private charities	5 (2)
Joint funding (Government and Industry)	1 (0)
Joint funding (Government and Private charity)	1 (0)
Not mentioned	63 (20)

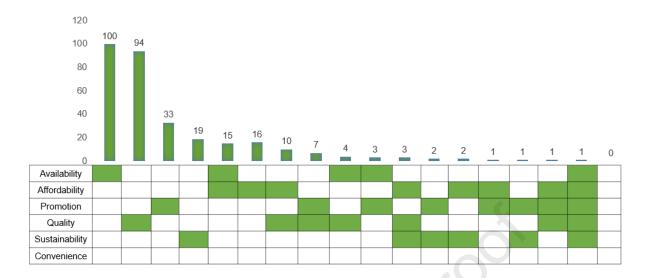
**Table 4**. Outcomes stated in articles included in the systematic review of the UK food environment (n=312)

	Outcomes n (%)		
Country	None- Descriptive	Diet	Health
UK wide	108 (54)	50 (79)	24 (58)
England	48 (23)	12 (18)	17 (40)
Scotland	26 (13)	2 (3)	0 (0)
Wales	9 (4)	0 (0)	0 (0)
Northern Ireland	9 (4)	0 (0)	0 (0)
Multiple countries within UK	6 (3)	0 (0)	1 (2)
Total	206	64	42





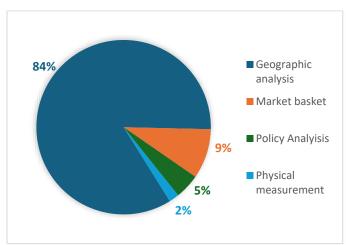


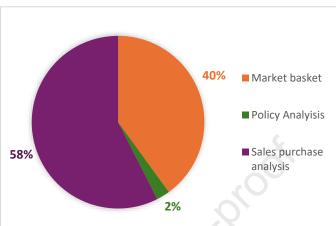


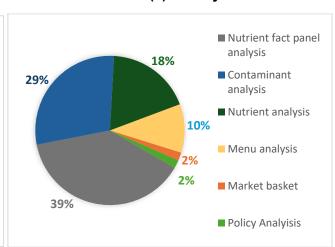
# (a) Availability

# (b)Affordability

## (c) Quality

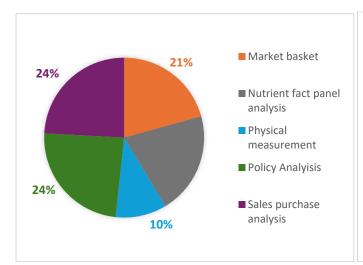


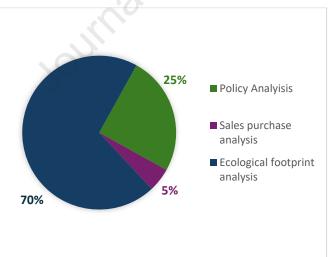




## (d) Promotion

# (e) Sustainability





### **Declaration of interests**

$\Box$ The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.
☑ The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

Dr Christian Reynolds reports a relationship with Centre for Food Policy, City St Georges, University of London that includes: consulting or advisory. Dr Christian Reynolds reports a relationship with The Alpro Foundation that includes: funding grants. Dr Christian Reynolds reports a relationship with The Folger Institute that includes: speaking and lecture fees. Dr Christian Reynolds reports a relationship with The Nutrition Society that includes: travel reimbursement. Dr Christian Reynolds reports a relationship with The Institute of Food Science & Technology, The Nutrition Society that includes: consulting or advisory. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.