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Systematic Review

Environmental determinants of fruit and vegetable consumption among adults: a systematic review

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The current ecological approach in health behaviour research recognises that health behaviour needs to be understood in a broad environmental context. This has led to an exponential increase in the number of studies on this topic. It is the aim of this systematic review to summarise the existing empirical evidence pertaining to environmental influences on fruit and vegetable (FV) consumption. The environment was defined as 'all factors external to the individual'. Scientific databases and reference lists of selected papers were systematically searched for observational studies among adults (18–60 years old), published in English between 1 January 1980 and 31 December 2004, with environmental factor(s) as independent factor(s), and fruit intake, vegetable intake or FV intake combined as one outcome measure as dependent factor(s). Findings showed there was a great diversity in the environmental factors studied, but that the number of replicated studies for each determinant was limited. Most evidence was found for household income, as people with lower household incomes consistently had a lower FV consumption. Married people had higher intakes than those who were single, whereas having children showed mixed results. Good local availability (e.g. access to one's own vegetable garden, having low food insecurity) seemed to exert a positive influence on intake. Regarding the development of interventions, improved opportunities for sufficient FV consumption among low-income households are likely to lead to improved intakes. For all other environmental factors, more replicated studies are required to examine their influence on FV intake.

Systematic review: Environmental determinants: Fruit consumption: Vegetable consumption

Non-communicable diseases, such as CVD and cancer, are the current major causes of death in developed countries (Murray & Lopez, 1997). Fruit and vegetable (FV) consumption plays a protective role in the onset of these chronic diseases (Steinmetz & Potter, 1996; Ness & Powles, 1997; Van Duyn & Pivonka, 2000), and a low FV intake is one of the leading risk factors for death from cancer worldwide (Danaei *et al.* 2005). Considerable reductions in morbidity and mortality from diet-related diseases can be achieved if the population adopts recommended dietary behaviours, including an adequate FV intake (McCullough *et al.* 2002). To understand and promote behaviour change towards recommended FV intakes, health behaviour research has predominantly focused on individual-level factors, including individuals' knowledge, intentions, attitudes, self-efficacy, motivation, taste, personal traits and other personal factors related to FV consumption (Krebs-Smith *et al.* 1995; Van Duyn *et al.* 2001; Satia *et al.* 2002; De Bruijn *et al.* 2005).

Over the past decade, there has been a movement towards a more ecological approach to people's health behaviour, which has resulted in an exponential increase in the number of studies on living environments (Humpel *et al.* 2002; Giles-Corti & Donovan, 2003). Environmental and policy interventions are now promoted as promising strategies for creating population-wide improvements in health behaviour (Booth *et al.* 2001; Hill *et al.* 2003; Stokols *et al.* 2003). However, no clear overview exists of environmental factors that have consistently been shown to be related to FV consumption. It is the aim of this systematic review to summarise the existing empirical evidence pertaining to the association between environmental influences and FV consumption, to identify knowledge gaps and to provide recommendations for policy and intervention development. More specifically, we address the following research questions: (1) Which environmental determinants of FV consumption have been

Abbreviation: FV, fruit and vegetable.

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examined in existing empirical research?, and (2) Which environmental factors does the existing evidence show a relationship with FV consumption?

Methods

As we were interested in any influence but individual-level factors, we kept our definition of the environment as broad as possible, i.e. 'all factors external to the individual' (Sallis & Owen, 2002). A framework used in previous research (Kamphuis *et al.* 2006), which identifies four categories of environmental factor related to health behaviour, was a helpful tool in classifying different environmental factors during the review process. The framework shares common features with ecological models (Cohen *et al.* 2000; Hovell *et al.* 2002), stressing the importance of multiple types of environmental influence that affect health behaviour. The four categories of this framework are:

1. accessibility and availability, including physical and financial accessibility of products and shops that are needed for an (un)healthy diet (e.g. access to FV shops, and the availability of FV and less healthy snacks);
2. social conditions, including social relationships (e.g. family/marital status), social support and psychosocial stress;
3. cultural conditions, including culture-specific eating patterns, health value orientations, food experiences in childhood and cultural participation;
4. material conditions, including financial situation (e.g. household income), material and social deprivation, and unfavourable working, housing and neighbourhood conditions (e.g. neighbourhood deprivation). These may affect behaviour through one of the previous environmental factors. For instance, a person's budgetary situation may partly determine his or her access to products and facilities. In addition, living or working in an unfavourable environment might induce stress, which might relate to indifference concerning a healthy diet.

Any environmental influence that could not be placed under the heading of one of these categories was referred to as 'other factors'.

The present study was conducted as part of a larger study examining the environmental determinants of several dietary outcomes, namely total energy, total fat, saturated fat and FV intakes. Search strategies therefore also included keywords for energy and fat intakes. Results on the environmental determinants of these dietary outcomes can be found elsewhere (K. Giskes *et al.* unpublished data).

Data sources and search strategy

The study protocol was based on guidelines from the *Cochrane Reviewer's Handbook* (Higgins & Green, 2005). The PubMed, PsychInfo, Web of Science and Human Nutrition databases were searched. Broad search terms were used so as not to miss any potentially relevant articles during the search procedure. The sensitivity of search strategies was tested by seeing whether they located key articles (Pollard *et al.* 2001; Morland *et al.* 2002) that were known by the researchers to fit the inclusion criteria. For each database, relevant indexing terms relating to energy, fat and FV intake and environmental determinants were selected and included in the search phrases. For example, in PubMed, the medical subject headings 'social environment', 'environment' and 'residence characteristics' were combined with the medical subject heading terms 'fruit', 'vegetables', 'energy intake', 'dietary fats', 'nutrition' and 'diet' to search for papers. Identical search terms were used for other databases. Detailed search strategies for every database can be found at http://mgzlx4.erasmusmc.nl/pwp/?ckamphuis.

Study selection

The selection criteria for inclusion were:

1. observational studies published in English between 1 January 1980 and 31 December 2004;
2. studies conducted among a population-based sample of adults (i.e. no patient groups) aged 18–60 years;
3. dependent variable(s) of intakes of energy, fat, fruits, vegetables, or fruits and vegetables combined as one outcome measure;
4. independent variable(s): variables that could be classified as an 'environmental' factor according to the definition of Sallis & Owen (2002), i.e. 'all factors external to the individual';
5. studies being conducted in an 'established market economy' as defined by the World Bank (2005).

Intervention studies were excluded from the scope of the current study. Those with a research design that made it impossible to decipher the effects of several environmental determinants on the outcome behaviour were also excluded. Studies among children were excluded, environmental factors typically investigated in relation to children's FV intake (e.g. parent's behaviour, parenting style, availability of fruits and/or unhealthy snacks at school; Brug & van Lenthe, 2005) differed significantly from those potentially relevant for adults.

The selection of articles located from the database searches took place in several steps. First, titles (and if necessary abstracts) were scanned by the first and second author independently (C. K., K. G.) to exclude those out of scope. When a sound judgement about an article's suitability could not be made based on title and/or abstract, the article remained in the review process. In the second step, the lists of included articles generated by both authors were compared. Discrepancies between the co-authors were discussed until consensus was reached. The full text of each remaining paper was then viewed by both C. K. and K. G., and papers were again excluded with the consensus of both authors. Finally, the reference lists of all remaining papers were scanned. The selection of studies from the reference lists followed the same steps as outlined above.

Data extraction and study assessment

The first two authors each extracted data from half of the studies. Each study's details were summarised in tables. Environmental factors, as reported by the participants, were referred to as 'self-reported' (e.g. marital status, household income), whereas factors extracted from objective databases

or systematically measured by the research team were called 'objective' (e.g. the actual number of supermarkets in a neighbourhood, as counted by the researcher).

Although we have made no formal attempt to gauge study quality, a crude indicator was developed to make a rough distinction between studies of acceptable quality and studies of limited quality. An assessment of sample size, response rate and whether adjustment was made for a limited set of confounders (age and sex) seemed to be sufficient to distinguish acceptable study quality. A study was judged as being of acceptable quality if it fulfilled at least two of the following criteria: sample size greater than 500, response rate over 55 % and adjustments made for potentially relevant confounders (Tabachnick & Fidel, 2001). Note that study quality was not an inclusion criteria, so no study was excluded from the review on the base of this crude quality measure.

Results

The literature searches yielded 7440 titles of potentially relevant articles in PubMed, fifty-eight titles in Psychinfo, 4828 titles in Web of Science and 8325 titles in Human Nutrition. After scanning titles and abstracts, a total of fifty-five potentially relevant articles was identified. This vigorous reduction in the number of potentially relevant articles based on title and abstract only was due to the broad search terms used, in combination with the strict inclusion criteria regarding dependent variables, and the overlap in titles identified by the databases. The reference lists of the fifty-five selected articles were scanned, which resulted in another twelve publications for inclusion. When examining the full texts of the total of sixty-seven articles, another twenty-six articles were excluded because they were either methodological or theoretical papers, described a naturally occurring intervention, or just mentioned environmental determinants of dietary behaviour in their discussion. Of the remaining forty-one articles, twenty-four articles had fruit and/or vegetable consumption as outcome variable(s). These papers and their findings are described below. The other papers had fat and/or energy intakes as outcome variables and are described in another review (K. Giskes *et al.* unpublished results).

Table 1 summarises the details of each study. Thirteen studies examined FV intake separately, nine studies combined FV intake as one outcome variable, and two presented results for all three outcomes (Naska *et al.* 2000; Pollard *et al.* 2001). Nine studies examined the associations between environmental determinant(s) and dietary outcome(s) for men and women separately; one study compared subgroups of blacks/whites (Morland *et al.* 2002). Studies were conducted in the UK (*n* 8), USA (*n* 7), Europe (*n* 7; e.g. Norway, Spain) and Australia (*n* 2). Dietary outcomes were predominantly measured with a food-frequency questionnaire and less often with a 7 d food consumption diary or 24 h dietary recall. All studies had a cross-sectional design. A wide range of different environmental determinants were studied. Seven of the twenty-four studies fulfilled one or none of the quality criteria, eleven studies met two quality criteria, and six studies fulfilled all three criteria.

Table 2 shows that the twenty-four studies examined a total of ninety-seven associations between environmental determinants and intakes, and fifty-seven of these were statistically significant. Detailed results for each dietary outcome are shown in Tables 3–5, later in the paper.

Fruit consumption

Material factors have been studied most often with regard to fruit intake (Table 3). People living in households with a higher income had a greater fruit consumption (Wandel, 1995; Giskes *et al.* 2002*a*,*b*). The same association was found among people living in a neighbourhood with a higher median income, even after adjustment for individual socio-economic status (Diez-Roux *et al.* 1999). Neighbourhood deprivation was associated with lower fruit consumption (Forsyth *et al.* 1994).

Accessibility and availability factors have received little attention in the literature to date. However, one study investigated the consequences of food insecurity on fruit intake, where food insecurity was defined as the limited or uncertain availability of nutritionally adequate and safe foods, including experiences such as running out of food, running out of money to buy food, or buying cheaper foods because of financial constraints (Tingay *et al.* 2003). Being food insecure was associated with significantly lower consumption (Tingay *et al.* 2003). Another study found that having a vegetable garden was positively and significantly associated with fruit consumption (Devine *et al.* 1999). Considerable disparities between European countries in terms of the availability of fruit at the national level were found, which are probably an explanation for the diverse percentage of low fruit consumers (< 150 g/person per day) between countries, ranging from 81 % of the population in Poland to 32 % in Greece (Naska *et al.* 2000).

The few studies examining social factors showed that being married and the number of people living in the household were positively related to fruit intake, whereas having children showed a mixed association (Gibney & Lee, 1993; Wandel, 1995; Devine *et al.* 1999; Pollard *et al.* 2001). Country and regional differences in fruit intake were significant for three out of five associations (Wandel, 1995; Agudo *et al.* 1999; Pan *et al.* 1999; Pollard *et al.* 2001; Papadaki & Scott, 2002). No significant associations were found for seasonal influences (Van Staveren *et al.* 1986; Ziegler *et al.* 1987).

Vegetable consumption

As for fruit, material factors were studied most often in relation to vegetable intake (Table 4). Household income demonstrated a consistent and significantly positive association with vegetable intake in seven associations (Wandel, 1995; Giskes *et al.* 2002*a*,*b*; Laaksonen *et al.* 2003), even after adjustment for education and occupational social class (Laaksonen *et al.* 2003). People living in higher-income neighbourhoods generally had higher energy-adjusted intakes of vegetables than those living in lower-income neighbourhoods (Diez-Roux *et al.* 1999), and this pattern was still present after adjustment for individual-level income. Living in the most socially disadvantaged neighbourhood of Glasgow was associated with the poorest intakes (Forsyth *et al.* 1994), including when individual characteristics such as occupational class and income were taken into account.

The same availability and social factors were studied for vegetables as for fruits, and associations were comparable to

Table 1. Details of studies included in the review

First author (year)	Country	Dietary outcome	Environmental determinants and measurement (self-reported (S) or objectively measured (O))		Aspects of study quality* N	%	C	Association(s) tested for subgroups†
Agudo (1999)	Spain	F, V	North/south location of residence within Spain	O	+	+	+	−
Billson (1999)	UK	FV	Region of residence within the UK, receiving benefits, marital status, having home-grown produce	S (all)	+	+		Men, women
Devine (1999)	USA	F, V	Having a vegetable garden, parental and marital status, presence of others during mealtime	S (all)	+	+	+	−
Dibsdall (2003)	UK	FV	Perceived accessibility of FV, perceived affordability of FV, perceived car access	S	+			−
Diez-Roux (1999)	USA	F, V	Median income of neighbourhood	S	+		+	Men, women
Forsyth (1994)	UK	F, V	Residing in a deprived *v.* advantaged area	O	+		+	−
Giskes (2002*a*)	Australia	F, V	Household income	S	+	+	+	Men, women
Giskes (2002*b*)	Australia	F, V	Household income	S	+	+	+	Men, women
Johansson (1998)	Norway	FV	Household income	S	+	+		Men, women
Johansson (1999)	Norway	FV	Residing in a rural *v.* urban area in Norway, household income	O	+	+	+	Men, women
Kintner (1981)	USA	FV	Aspects of family functioning (cohesion, expressiveness, conflict, independence, achievement orientation, intellectual-cultural orientation, active-recreational orientation, moral-religious emphasis, organisation, control)	S				Men, women
Laaksonen (2004)	Finland	V	Household income	O	+	+	+	Men, women
Morland (2002)	USA	FV	Whether or not there were the following food stores in the census tract (as approximation of neighbourhoods): Supermarkets Grocery stores Full-service restaurants Fast-food restaurants	O	+		+	Blacks, whites
Naska (2000)	Europe	F, V, FV	How much fruit and vegetables were available in the food supply in different countries	O	+			−
Pan (1999)	USA	F, V	Residing in the US for a minimum of 6 months (compared with an Asian country)	S				−
Papadaki (2002)	UK	F, V	Residing in Scotland (compared with Greece)	S		+		−
Pollard (2001)	UK	F, V FV	Region of residence in the UK, having children, marital status	S (all)	+	+		−
Shohaimi (2004)	UK	FV	Deprivation of residential area	S	+		+	Men, women
Steptoe (2004)	UK	FV	Social support: from family, from others	S			+	−
Subar (1994)	USA	FV	Season (summer or winter)	O	+		+	−
Tingay (2003)	UK	F, V	Food insecurity‡	S		+	+	−
Van Staveren (1996)	Netherlands	F, V	Season (summer or winter)	O			+	−
Wandel (1995)	Norway	F, V	Having children, household size, household income, region of residence in Norway	S (all)	+	+		−
Ziegler (1987)	USA	F, V	Season (summer–spring or winter–autumn)	S	+	+		−

F, fruit intake; V, vegetable intake; FV, fruit and vegetable intake combined in one outcome measure.

* Study quality aspects. N, +, sample of over 500; %, +, response rate is reported; C, +, adjustments made for at least age and sex.

† −, Associations not tested for any subgroups.

‡ Food insecurity has been defined as the limited or uncertain availability of nutritionally adequate safe foods, including experiences such as running out of food, running out of money to buy food or buying cheaper foods because of financial constraints (Tingay *et al.* 2003).

those seen with fruit intake, as described earlier. Country and regional differences in vegetable intake were often significant (Wandel, 1995; Agudo *et al.* 1999; Pan *et al.* 1999; Pollard *et al.* 2001; Papadaki & Scott, 2002). Winter was negatively associated with vegetable intake in two studies (Van Staveren *et al.* 1986; Ziegler *et al.* 1987).

Fruit and vegetable consumption

The group of environmental factors that have been studied most often are those related to the accessibility and availability of FV, although only five of the fourteen associations tested were statistically significant (Table 5). Men and women who reported eating home-grown produce had a significantly higher FV consumption than those who did not (Billson *et al.* 1999). The presence of a supermarket in the census tract where a participant lived had a significant relationship with FV intake for black residents (Morland *et al.* 2002). The presence of other food facilities in the census tract showed no significant relationship with the FV intake of black or white individuals (Morland *et al.* 2002). Another study showed that positive perceptions of the accessibility of shops, the variety of FV in the shops and the affordability of FV were all positively related to FV intake, whereas car access showed no significant results (Dibsdall *et al.* 2003). Considerable differences between European countries in terms of FV availability at the national level were found, with parallel differences in FV consumption between the populations (Naska *et al.* 2000).

Other categories of factors were less frequently studied for FV than for fruit consumption and vegetable consumption as separate outcomes, but the results were comparable. One exception was household income, for which no significant difference in FV intake between high-income and low-income households was found for men (Johannson & Andersen, 1998) and women (Johansson *et al.* 1999), although the latter study showed a significant positive association between income and FV intake for men. People receiving benefits consumed significantly fewer FV than people not in receipt of benefits (Billson *et al.* 1999). Residential

Table 2. Summary of the number of associations between environmental determinants and fruit and vegetable (FV) consumption

Environmental determinants	Fruit intake	Vegetable intake	FV intake
Accessibility factors			
Availability of FV at national market	1	1	1
Grocery store in the census tract			2
Supermarket in the census tract			**+1**/1
Full-service restaurant in the census tract			2
Fast-food restaurant in the census tract			2
Perceived accessibility (of shops, of FV in shops)			**+1**
Perceived affordability (of FV in shops)			**+1**
Household food insecurity	**−1**	**−1**	
Car access			1
Having a vegetable garden or home-grown produce	**+1**	**+1**	**+2**
Social factors			
Being married	**+1**/1	**+2**	**+2**/+1
Household size	**+1**	**+1**	
Having child(ren) (compared with no children)	**+1/−2**	**−1/+1**/−1	+1
Family functioning			1
Social support from family members			**+1/+1**
Social support from others			**+1**
Cultural factors			
Presence of others during mealtimes	**+1**	1	
Intellectual-cultural orientation of family			**+1**
Material factors			
Median income of neighbourhood	**+1**/+1	+2	
Neighbourhood deprivation	**−1**	**−1**	**−1**/1
Household income	**+4**/+1	**+7**	**+1**/+1/−2
Receiving benefits			**−2**
Other factors			
Living in a rural area (compared with urban)			**−2**
Living in a northern region of Norway	1	**−1**	
Region of residence in Spain	1	1	
Living in the north of the UK	**−1**	**−1**	**−1**/2
Living in London/South-East of the UK			**+1**
Residing in the USA (instead of Asia)	**+1**	**−1**	
Residing in Scotland (instead of Greece)	**−1**	**−1**/1	**−1**/1
Winter (compared with summer)	+2/−1/−1	**−1**/−1	+2/−1

When a study tested associations for subgroups separately, all associations are reported in this table. Results from acceptable as well as low-quality studies are presented.

The numbers in the table should be interpreted as follows: **bold**, number of significant effects found for the combination determinant–dietary outcome; unbold, number of non-significant effects found for the combination determinant–dietary outcome, or for which information on significance was not available; +, positive association between environmental determinant and dietary outcome; −, negative association between environmental determinant and dietary outcome. Some non-significant associations do not have a plus or minus sign as this information was not available in all cases.

Table 3. Results of studies examining environmental determinants of fruit consumption

First author (year)	Sample size (response rate %)	Environmental determinant(s)	Findings	Was association significant?*	Adjusted for
Accessibility and availability					
Devine (1999)	592 (82 %)	Having a vegetable garden	Having a vegetable garden was positively and significantly associated with fruit consumption	Y	Age, gender, education, race
Naska (2000)	142 715 households (response rate % not available)	How much fruit was available in the food supply in different countries	In Poland, a country with a low availability of fruit (i.e. 100 g/person per day) 81 % of the population did not reach the recommended intake. In Greece, a country with high availability of fruit (i.e. 350 g/person per day) 32 % of the population did not reach WHO recommendations	Not available	Nil
Tingay (2003)	431 (87 %)	Food insecurity	Participants with food insecurity had a likelihood of 0·57 (CI 0·36, 0·90) for consuming fruit daily compared with their counterparts who were food secure	Y	Age, sex
Social factors					
Devine (1999)	592 (82 %)	Parental and marital status	Being married + having a young child, or being single + having a young child (*v.* being married + having no child) was positively and significantly associated with fruit consumption among whites	Y	Age, gender, education, race
Pollard (2001)	35 367 women only (58 %)	Having children, marital status	Those without children consumed 0·26 portions of fruit more than participants with children. Single participants consumed 0·21 fewer portions of fruit than their married counterparts	Children: Y Marital status: Y	Nil
Wandel (1995)	14 960 (77 %)	Having children, household size	Those with children were 0·90 times more likely to consume fruits seldomly than were participants without. Participants in households with more than two people were 1·54 times less likely to consume fruits seldomly	Y for children and household size	Nil
Cultural factors					
Devine (1999)	592 (82 %)	Presence of others during mealtime	Eating with others was positively associated with fruit consumption	Y	Age, gender, education, race
Material factors					
Diez-Roux (1999)	13 095 (response rate % not available)	Median income of neighbourhood	Men and women in the poorest neighbourhoods were 1·67 and 1·41 times more likely to have low fruit consumption (respectively) than those in the most advantaged neighbourhoods.	Men: Y Women: NS	Age, gender, race, energy intake, field centre, individual-level income
Forsyth (1994)	691 (response rate % not available)	Living in a deprived *v.* advantaged area	Residents of disadvantaged areas consumed 3·4 fewer servings of fruit per week compared with those living in the most advantaged areas.	Y	Age, gender, occupational class
Giskes (2002*a*)	8883 (61 %)	Household income	Men and women in the lowest income quintile consumed 77 g and 73 g less fruit (respectively) in the previous 24 h than their counterparts in the highest income quintile	Y for both men and women	Age, gender, energy intake
Giskes (2002*b*)	7695 (61 %)	Household income	Men and women in the lowest income quintile were 2·3 and 2·5 times more likely (respectively) *not* to consume vegetables on a daily basis	Y for both men and women	Age, gender, energy intake
Wandel (1995)	14 960 (77 %)	Household income	High-income groups were − 1·78 times less likely to consume fruits seldomly compared with low-income groups	NS for household income	Nil

Table 3. *Continued*

First author (year)	Sample size (response rate %)	Environmental determinant(s)	Findings	Was association significant?*	Adjusted for
Other factors					
Agudo (1999)	41 448 (55–60 % depending on region)	North/south location of residence within Spain	Overall, no consistent differences were observed between southern and northern regions regarding fruit intake (one region from the south consumed higher amounts of fruits than the remaining regions)	NS	Age, gender
Pan (1999)	63 (53 %)	Residing in the USA for a minimum of 6 months instead of residing in an Asian country	When moving to the USA, the frequency of fruit consumption increased from twelve to fifteen times a week compared with when living in the Asian country of origin	Y	Nil
Papadaki (2002)	80 (95·2 %)	Residing in Scotland instead of Greece	Moving to Scotland (from Greece) resulted in 40 % of the students changing their fresh fruit consumption from ≤ once daily to < once daily	Y	Nil
Pollard (2001)	35 367 women only (58 %)	Region of residence in the UK	Participants in the North West of the UK consumed 0·39 portions fewer than those in the south west	Y	Nil
Subar (1994)	20 143 (response rate % not available)	Season (summer or winter)	In winter, men consumed 0·7 servings of fruits per week more than in the summer. In winter, women consumed 0·9 servings per week more than in the summer	Not available	Age, race, region, education, poverty index
Van Staveren (1996)	114 women only (response rate % not available)	Season (summer or winter)	Fruit consumption was 7 g lower in winter than summer	NS	Adjustment for time of the week: weekends, Friday, Monday–Thursday
Wandel (1995)	14 960 (77 %)	Region of residence in Norway	Living in the north, middle, south/west, east or capital of Norway had no significant influence on being a frequent fruits consumer	NS	Nil
Ziegler (1987)	900 (64 %)	Season (summer–spring or winter–autumn)	In winter–autumn, participants ate forty servings of fruit less per month than in summer–spring	Not available	Nil

Studies are grouped by the environmental determinant(s) they examine (following the classification of the framework). Within each subgroup, studies are grouped by specific determinants.
*Yes (Y); the effect was statistically significant ($P \leq 0{\cdot}05$).

Table 4. Results of studies examining environmental determinants of vegetable consumption

First author (year)	Sample size (response rate %)	Environmental determinant(s)	Findings	Was association significant?*	Adjusted for
Accessibility and availability					
Devine (1999)	592 (82 %)	Having a vegetable garden	Having a vegetable garden was positively and significantly associated with vegetable consumption	Y	Age, gender, education, race.
Naska (2000)	142 715 households (response rate % not available)	How widely vegetables are available in the food supply in different countries	In Norway, a country of low availability (i.e. 102 g/person per day), 93 % of the population did not reach the recommended intake for vegetables, whereas in Greece, a country of high availability (267 g/person per day), 56 % of the population did not reach WHO recommendations	Not available	Nil
Tingay (2003)	431 (87 %)	Food insecurity	Participants with food insecurity had a likelihood of 0·43 (CI 0·25, 0·74) for consuming vegetables daily compared with their counterparts who were food-secure	Y	Age, sex
Social factors					
Devine (1999)	592 (82 %)	Parental and marital status	Being married + having a young child, or being single + having no child (*v.* being single + having a young child) was positively and significantly associated with vegetable consumption	Y	Age, gender, education, race
Pollard (2001)	35 367 women only (58 %)	Having children, marital status	Those without children consumed 0·17 portions fewer than participants with children. Single participants consumed 0·60 fewer portions of vegetables than their married counterparts	Children: Y Marital status: Y	Nil
Wandel (1995)	14 960 (77 %)	Number of children in household, household size	Those with children were −0·15 times less likely to be frequent consumers of vegetables than participants without. Participants in households with more than two people were 1·11 times more likely to be frequent vegetable consumers than those living alone	Having children: NS Household size: Y	Nil
Cultural factors					
Devine (1999)	592 (82 %)	Presence of others during mealtime	Eating with others was not associated with vegetable consumption.	Not available	Age, gender, education, race.
Material factors					
Diez-Roux (1999)	13 095 (response rate % not available)	Median income of neighbourhood	Men and women in the poorest neighbourhoods were 1·20 and 1·11 times more likely to have a low vegetable consumption (respectively) than those in the most advantaged neighbourhoods	NS men and women	Age, gender, race, energy intake, field centre, individual-level income
Forsyth (1994)	691 (response rate % not available)	Living in a deprived *v.* advantaged area	Residents of deprived areas reported consuming 2·2 servings fewer of vegetables per week than those in advantaged areas	Y	Age, gender, occupational class.
Giskes (2002*a*)	8 883 (61 %)	Household income	Men and women in the lowest income quintile consumed 18 g and 16 g fewer vegetables (respectively) in the previous 24 h than did their counterparts in the highest income quintile	Y for men and women	Age, gender, energy intake.

Table 4. *Continued*

First author (year)	Sample size (response rate %)	Environmental determinant(s)	Findings	Was association significant?*	Adjusted for
Giskes (2002*b*)	7695 (61%)	Household income	Men and women in the lowest income quintile were 1·6 times more likely *not* to consume vegetables on a daily basis	Y for men and women	Age, gender, energy intake
Laaksonen (2004)	1992 (70%)	Household income	Men and women in low-income households were 1·54 and 1·42 times more likely to be low vegetable consumers (respectively than those in high-income households	Y for men and women	Age, study year, education and occupation, marital status, having dependent children in the family
Wandel (1995)	14960 (77%)	Household income	High-income groups were −0·89 times less likely to consume vegetables seldomly than low-income groups	Y	Nil
Other factors					
Agudo (1999)	41448 (55–60% depending on centre)	North/south location of residence within Spain	Overall, no consistent differences were observed between southern and northern regions regarding fruit intake (one region from the south consumed higher amounts of vegetables, whereas another from the north had lower amounts of vegetables than the remaining regions)	NS	Age, gender
Pan (1999)	63 (53%)	Residing in the USA for a minimum of 6 months instead of residing in an Asian country	When moving from an Asian country to the USA, the frequency of vegetable consumption decreased from twenty-six to twenty-one times per week	Y	Nil
Papadaki (2002)	80 (95·2%)	Residing in Scotland instead of Greece	Moving to Scotland (from Greece) resulted in 52% of the students changing their raw vegetable consumption from once or more per day to less than once per day	Raw vegetables: Y	Nil
			Moving to Scotland (from Greece) had no significant effect on the consumption of cooked vegetables	Cooked vegetables: NS	
Pollard (2001)	35367 women only (58%)	Region of residence	Participants in the north-west consumed 0·32 portions fewer than those in the south west	Region of residence: Y	Nil
Wandel (1995)	14960 (77%)	Region of residence	Those living in the north of Norway were −0·73 times less likely to be frequent vegetable consumers than those living in Oslo	Y	Nil
Van Staveren (1986)	114 women only (response rate % not available)	Season: summer or winter	Vegetable consumption was 45 g lower in winter than summer	Y	Day of the week
Ziegler (1987)	900 (64%)	Season: summer–spring or winter–autumn	In winter–autumn, participants ate eleven servings of vegetables fewer per month than in summer–spring	Not available	Nil

Studies are grouped by the environmental determinant(s) they examine (following the classification of the framework). Within each subgroup, studies are grouped by specific determinants.
*Yes (Y); the effect was statistically significant ($P \leq 0{\cdot}05$).

Table 5. Results of studies examining environmental determinants of fruit and vegetable (FV) consumption

First author (year)	Sample size (response rate %)	Environmental determinant(s)	Findings	Was association significant?*	Adjusted for
Accessibility and availability					
Billson (1999)	1444 (70 %)	Having home-grown produce	Eating home-grown produce was very significantly associated with higher FV consumption. More than 40 % of the men and women in the highest FV consumption quartile consumed home-grown produce	Y for men and women	Nil
Dibsdall (2003)	680 (23 %)	Accessibility (of shops, choice of FV in shops), affordability, car access	People who indicated eating five or more portions of FV/d had a significantly more positive attitude towards their accessibility of FV than people eating two or fewer FV portions/d	Accessibility: Y	Nil
			People who indicated eating five or more portions of FV/d had a significantly less negative attitude towards the affordability of FV than people eating four or fewer FV portions per day	Affordability: Y	
			68 % of the people who indicated eating five or more portions had access to a car, whereas 55 % and 48 % of those who ate 0–2 and 3–4 portions, respectively, had car access	Car access: not reported	
Morland (2002)	10 623 (response rate % not available)	Whether or not there were the following food stores in the census tract:	Likelihood of reaching FV recommendations for white Americans (*n* 8 231) with the following stores in the census tract:	White Americans: NS for all types of food outlets	Education, income and other types of food store
		Supermarkets	Supermarkets 1·08 (CI 0·89, 1·30)		
		Grocery stores	Grocery stores 0·93 (CI 0·78, 1·10)		
		Full-service restaurants	Full-service restaurants 0·94 (CI 0·75, 1·19)		
		Fast-food restaurants	Fast-food restaurants 1·12 (CI 0·91, 1·37)		
			Likelihood of reaching FV recommendations for black Americans (*n* 2 392) with the following stores in the census tract:		
			Supermarkets 1·54 (CI 1·11, 2·12)	Black Americans: Supermarkets: Y Other outlets: NS	
			Grocery stores 1·07 (CI 0·83, 1·38)		
			Full-service restaurants 1·06 (CI 0·79, 1·41)		
			Fast-food restaurants 0·94 (CI 0·74, 1·21)		
Naska (2000)	142 715 households (response rate % not available)	How much FV were available in the food supply in different countries	In Ireland, a country of low availability (i.e. 233 g/person per day), 88 % of the population did not reach the recommended intake for FV, whereas in Greece, a country with a high availability (617 g/person per day), 37 % of the population did not reach WHO recommendations	Not available	Nil
Social factors					
Billson (1999)	1444 (70 %)	Marital status	Among men, being married was associated with increased FV intake and being single or divorced/-separated was associated with low FV intake	Men: Y Women: NS	Nil
Kintner (1981)	84 (response rate % not available)	Overall family functioning	Overall, the associations of family functioning with FV intake were small and non-significant	Overall family functioning: NS	Nil

Table 5. *Continued*

First author (year)	Sample size (response rate %)	Environmental determinant(s)	Findings	Was association significant?*	Adjusted for
		Cohesion aspect of family functioning (whether family members helped and supported each other)	Family help and support was significant and positively correlated with FV consumption among women (but not among men)	Y for help and support among women	
Pollard (2001)	35 367 women only (58 %)	Having children, marital status	The likelihood of being a high FV consumer was 1·09 (CI 0·98, 1·21) for women with children compared with women with no children, and 1·62 (CI 1·38, 1·91) for married women compared with single women	Having children: NS Married: Y	Age, physical activity status, vegetarian status, intake of vitamin supplements, illnesses, alcohol consumption, education level, employment status, occupation, region of residence
Steptoe (2004)	218 (response rate % not available)	Social support: from family, from others	Regression co-efficient for social support (family) 0·10 (CI 0·012, 0·18); change in variance 1·9 %	Social support (family): Y	Experimental group, gender, ethnicity, income, smoking, baseline FV consumption
			Regression co-efficient for social support (other) 0·10 (CI 0·011, 0·19); change in variance 1·8 %	Social support (other): Y	
Cultural factors					
Kintner (1981)	84 (response rate % not available)	Intellectual-cultural aspect of family functioning	The intellectual-cultural aspect of family functioning (whether the family was concerned about political, social, intellectual and cultural activities) was significantly correlated with FV intake for women	Y for intellectual-cultural aspect among women	Nil
Material factors					
Billson (1999)	1444 (70 %)	Receiving benefits	Being in receipt of benefits was negatively associated with FV intake	Men: Y Women: Y	Nil
Johansson (1998)	1564 (87 %) + 3144 (63 %)	Household income	Low-income men consumed 1 g less FV/d than high-income men. Low-income women consumed 35 g more FV/d than their high-income counterparts	Men: NS Women: Y	Nil
Johansson (1999)	3144 (63 %)	Household income	Low-income men consumed 32 g less FV than high-income men. Low-income women consumed 7 g more FV than high-income women	Men: Y Women: NS	Age, gender, education
Other factors					
Billson (1999)	1444 (70 %)	Region of residence in the UK	Among women, living in Scotland was negatively associated with FV intake, whereas living in London or the South East of the UK was positively associated with FV consumption	Women: Y Men: NS	Nil
Johansson (1999)	3144 (63 %)	Residing in an urban *v.* rural area in Norway	Men living in rural areas consumed 47 g less FV than those in cities, whereas women in rural areas consumed 58 g less FV than their counterparts living in cities	Men: Y Women: Y	Age, gender, education
Papadaki (2002)	80 (95·2 %)	Residing in Scotland instead of Greece	The median estimated daily intake of FV decreased from 363 g in Greece to 124 g in Glasgow	Not available	Nil

Table 5. *Continued*

First author (year)	Sample size (response rate %)	Environmental determinant(s)	Findings	Was association significant?*	Adjusted for
Pollard (2001)	35 367 women only (58 %)	Region of residence in the UK	The likelihood of being a high FV consumer was 0·71 (CI 0·55, 0·93) for women living in the North West of the UK and 2·09 (CI 0·62, 6·99) for women in Northern Ireland, compared with women in the North East	NS	Age, physical activity status, vegetarian status, intake of vitamin supplements, illnesses, alcohol consumption, marital status, education level, employment status, occupation, having children
Shohaimi (2004)	22 562 (38 %)	Deprivation of residential area	Men and women in the most deprived areas consumed 26·5 g/d and 16 g/d less FV, respectively, compared with their most advantaged counterparts	Men: Y Women: NS	Occupational class, education, age
Subar (1994)	20 143 (response rate % not available)	Season (summer–winter)	In winter, men consumed 0·5 servings/week more than in the summer. In winter, women consumed 1 serving/week more than in the summer	Not available	Age, race, region, education, poverty index
Ziegler (1987)	900 (64 %)	Season (summer–spring or winter–autumn)	In winter–autumn, participants ate forty-nine servings of FV /month less than in summer–spring	Not available	Nil

Studies are grouped by the environmental determinant(s) they examine (following the classification of the framework). Within each subgroup, studies are grouped by specific determinants.
* Yes (Y); the effect was statistically significant ($P \leq 0·05$).

area-based deprivation significantly predicted FV intake, independently of occupational class and educational level (Shohaimi *et al.* 2004). Significant negative associations between living in a rural area and FV intake were found for men and women (Johansson *et al.* 1999).

Discussion

We performed a systematic review of the environmental determinants of FV intake. Household income was investigated in six studies that showed, in general, consistent positive associations with FV intake (Wandel, 1995; Johannson & Andersen, 1998; Johansson *et al.* 1999; Giskes *et al.* 2002*a*,*b*; Laaksonen *et al.* 2003). Being married (Billson *et al.* 1999; Devine *et al.* 1999; Pollard *et al.* 2001) and residing in an advantaged area (even after adjustment for individual characteristics such as occupation or income level; Forsyth *et al.* 1994; Diez-Roux *et al.* 1999; Shohaimi *et al.* 2004) showed positive, albeit not always significant, associations with FV consumption, in at least three studies of acceptable quality. Good local availability of FV (e.g. by growing FV in one's own garden, or having low food insecurity) also seemed to be positively related to intake, although the evidence was limited. Overall conclusions should be drawn with caution owing to the small number of studies for each specific environment–intake association.

Income and being married, two of the factors studied most frequently, may not sound like typical environmental influences. However, income has elsewhere been described as a feature of an individual's microenvironment (Swinburn *et al.* 1999). In our view, household income is a true environmental influence as all household members are exposed to one and the same household income whether they are breadwinner, homemaker or child. Being married (i.e. living together with a partner), compared with being single, can be viewed as a socio-environmental factor as the presence of a partner may affect a person's FV intake via the partner's eating patterns, social support, socio-cultural norms, home availability of FV (when the partner buys most of the groceries, as is often the case for men) and so on.

The finding that people living on a smaller household budget or in a disadvantaged area consume fewer FV may be due to perceptions that FV are expensive (Mooney, 1990; Sooman *et al.* 1993; Kamphuis *et al.* 2006), have a short shelf life or are difficult to store (Giskes *et al.* 2002*b*). Although food has been found to be equally or lower priced in deprived areas (Mooney, 1990; Cummins & Macintyre, 2002), people pay a relatively higher premium on the price of healthy compared with less healthy foods in deprived areas (Mooney, 1990; Sooman *et al.* 1993). Interventions to improve opportunities for sufficient FV consumption among low-income households seem necessary in order to improve intake. Offering discount coupons for FV-rich menu items has been shown to be an effective strategy to encourage the consumption of these foods in certain venues (Glanz & Hoelscher, 2004). Nevertheless, more research into the associations between household income and FV consumption is necessary to better understand the precise mechanisms that lead from low incomes to low intakes.

Three dependent variables, i.e. fruit consumption, vegetable consumption and FV consumption combined, were studied in

the present study. As can be seen from Table 2, no major differences in their relationships with environmental factors were observed. However, associations have been studied most for FV consumption when combined (forty-five tests) and less for fruit consumption and vegetable consumption separately (twenty-seven and twenty-eight tests respectively). Researchers might assume that environmental determinants relate to fruit consumption and vegetable consumption in the same way, and therefore take both dietary measures together as one outcome. It seems reasonable to assume that, for instance, the presence of a supermarket in one's neighbourhood relates to the accessibility of fruits and vegetables in the same way. Other factors, however, can be important for fruit rather than for vegetable intake (e.g. the presence of fruit in the fruit bowl on the table at home may elicit fruit consumption) and vice versa (e.g. culture-specific eating patterns may determine the amount of vegetables eaten during meals). Other research has found that similar behaviours (such as walking and cycling) do in fact show different associations with some environmental factors (Cervero & Duncan, 2003; van Lenthe *et al.* 2005). Hence, it seems important for future research to investigate environmental influences on fruit consumption and vegetable consumption separately.

Four categories of environmental variables were distinguished in the present study. We have found about an equal, albeit fairly low, number of studies examining accessibility and social and material factors (resulting in twenty-four, twenty and twenty-six tests, respectively). Only two studies examined cultural factors (three tests in total), of which one study was of doubtful quality (Kintner *et al.* 1981). This very low number of studies for cultural factors might be surprising as culture has been known as the foundation that underlies food choices in that it determines what people consider to be acceptable and preferable foods, and the amounts and combinations of food they choose (Nestle *et al.* 1998). On the other hand, cultural influences may be difficult to conceptualise and measure, and they have rarely been specified in health behaviour models. One exception is the theory of triadic influences, which incorporates the cultural environment as one of the ultimate influences on health behaviour (Flay & Petraitis, 1994). A more specific conceptualisation of cultural factors in health behaviour models may be needed to explore the pathways between, for instance, culture-specific eating patterns and FV consumption.

Two groups of factors, regional and seasonal influences, were grouped under a separate heading of 'other factors', as it was unclear how they related to FV intake. This could, for instance, be via the availability of FV in a certain area or season, or via culturally determined FV consumption patterns in an area or season. Although studies were often of low quality, it can be concluded that living in the north of the UK is not beneficial for one's FV consumption compared with living in other parts of the UK (Billson *et al.* 1999; Pollard *et al.* 2001) or living in Greece (Papadaki & Scott, 2002). This can be related to the fact that average income levels are generally known to be lower in the North East of England and Scotland compared with the South East of England. Seasonal influences showed mixed associations with intakes.

Study limitations

There were several limitations of this review study that have to been taken into account when interpreting the findings. The search strategies did not locate 'grey literature' (e.g. unpublished studies, local reports, PhD and Masters abstracts). It was, however, reasoned that problems with including grey literature (poor study quality owing to lack of peer review (Angell, 1989) and the time and costs involved in identifying and retrieving grey literature (McAuley *et al.* 2000)) outweighed the possible advantage of preventing our results from the influence of publication bias. However, we could have missed important 'grey literature' that could have contributed to this review (e.g. White *et al.* 2001).

Another limitation is that measurements of dietary intakes differed between studies. In sixteen papers, intakes were measured by a food-frequency questionnaire, with the number of food items ranging from two (one for fruit and one for vegetables; Steptoe *et al.* 2004) to 217 different food items (Pollard *et al.* 2001). Less frequently used measurement tools were a 7 d food-consumption diary (Billson *et al.* 1999) and a 24 h dietary recall (Van Staveren *et al.* 1986; Giskes *et al.* 2002*a*,*b*). The validity of the measures was hardly discussed in these papers. It is likely that the variation in measures for fruit and vegetable intakes as well as for the environmental determinants, might have contributed to 'noise' or variation in the associations found.

Three other limitations directly relate to the relatively few studies found in this area of research. First, very little is known about appropriate confounders in the relationship between the environment and FV intake. Some studies included in this review may 'overcorrect' for individual factors that are on the pathway between the environment and FV intake (e.g. being a vegetarian), which wrongly diminishes the actual association. In studies that have not corrected for confounders or only adjusted for a limited set of these (age, sex, education/occupation), associations might be overestimated. This makes it possible that this review might give an 'overestimated' overview of relevant environmental factors. It is likely that future research, when taking correct confounders into account, will show that some associations are non-existent.

Moreover, this review lacks an estimation of the relative importance of environmental compared with individual-level factors, as most studies did not report on the strength of the associations found. Just one study reported that social support from the family, and social support from others accounted for 1·9 % and 1·8 % of the variance in FV intake, respectively (Steptoe *et al.* 2004). Compared with the proportion of variance explained by typical individual-level factors, this is rather small (Krebs-Smith *et al.* 1995; Satia *et al.* 2002). For example, four psychosocial correlates: the importance of eating vegetables; the health benefits; the convenience and taste of raw vegetables; and the taste of cooked vegetables, explained 14 % of the variance in vegetable intake (Satia *et al.* 2002). In general, the proportion of variance explained by environmental factors will be substantially smaller than for individual-level factors, as the latter factors are much more closely related to the actual behaviour. Subsequent research in this area should focus on the relative importance of these factors.

Finally, the fact that the studies in the present review originated from different countries makes the interpretation of the results difficult. Relevant availability-related influences may be country specific, for example, neighbourhood differences

in the accessibility of supermarkets and grocery stores appear to exist only in the USA (Cummins & Macintyre, 2006). As can be seen in Table 1, factors related to local availability of FV (i.e. having one's own vegetable garden, low food insecurity, the presence of a supermarket in the residence area, positive perceptions of the accessibility of FV shops) were positively associated with intakes in the USA as well as the UK. Nevertheless, the availability of FV at the national level differed considerably for European countries (in 1990), ranging from 233 g FV/person per day in Ireland to a total of 617 g/person per day in Greece, with parallel differences in intakes (Naska *et al.* 2000).

Comparison with other reviews

By searching several databases and the studies' reference lists, we located four other reviews on the environmental determinants of either FV consumption or a healthy diet. These reviews differed from ours in that they were not performed in a systematic way, had a more narrative tenor or focused on other dietary outcomes. Our findings are in line with these studies regarding the associations of accessibility and household income with FV consumption (Krebs-Smith *et al.* 1995; Pollard *et al.* 2002) or healthy eating (Glanz *et al.* 2005; Popkin *et al.* 2005).

Individual consumers need sufficient access to quantities of fruits and vegetables at affordable prices and in forms that meet standards for quality, taste, palatability and convenience to be able to meet recommended intake levels. This is often not the case, especially among low-income households in poor central cities and sparsely populated rural areas (Krebs-Smith & Kantor, 2001). The increasing number of meals being consumed away from home was also stressed as an important factor for unhealthy eating (Glanz *et al.* 2005; Popkin *et al.* 2005). Away-from-home foods typically have higher energy and fat densities and larger portion sizes, which are associated with a decreased quality of the diet and increased total energy intake (Popkin *et al.* 2005). Reviews also stressed the necessity to improve our understanding of food environments, referring to the small number of studies in this research area and how existing studies suffer many limitations (e.g. small population sizes, non-longitudinal designs, geographic isolation; Glanz *et al.* 2005; Popkin *et al.* 2005).

Conclusions and recommendations

There is a clear need for more research on supportive food environments, ideally for different dietary intakes separately, as relevant environmental factors may differ for various outcomes. This research should preferably be longitudinal, to understand the causal pathways between the environment and intakes. Studies should investigate the strength of the associations observed, or specifically study the relative importance of environmental compared with individual-level factors, as has been done for environment–physical activity associations (Giles-Corti & Donovan, 2002, 2003). A good theoretical framework should underlie this research so that hypotheses can be formed and tested to further develop scientific knowledge and theory in this emerging field. Specifically, extensive research into accessibility-related, availability-related and cultural influences may result in new explanations for variations in FV consumption and offer new avenues to promote behaviour change towards recommended FV intakes.

In summary, with the data available, it can be concluded that the consumption of FV is likely to be higher among people with higher incomes, those who are married, those living in an advantaged neighbourhood and/or those who have a good local availability and accessibility of FV. The evidence base for the latter determinants is still, however, too thin to justify large-scale interventions targeting those environmental determinants. The only exception to this is household income. Interventions to improve opportunities for sufficient FV consumption among low-income households are likely to lead to improved intakes.

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