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Perceived and objective measures of the food store environment and the association with weight and diet among low-income women in North Carolina

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Abstract

Objective: The present study aimed to highlight the similarities and differences between perceived and objective measures of the food store environment among low-income women and the association with diet and weight.

Design: Cross-sectional analysis of food store environment. Store level was characterized by: (i) the availability of healthy foods in stores where participants shop, using food store audits (objective); and (ii) summary scores of self-reported perception of availability of healthy foods in stores (perceived). Neighbourhood level was characterized by: (i) the number and type of food stores within the census tract (objective); and (2) summary scores of self-reported perception of availability of healthy foods (perceived).

Setting: Six counties in North Carolina.

Subjects: One hundred and eighty-six low-income women.

Results: Individuals who lived in census tracts with a convenience store and a supercentre had higher odds of perceiving their neighbourhood high in availability of healthy foods (OR = 6·87 (95 % CI 2·61, 18·01)) than individuals with no store. Overall, as the number of healthy foods available in the store decreased, the probability of perceiving that store high in availability of healthy foods increased. Individuals with a supercentre in their census tract weighed more (2·40 (95 % CI 0·66, 4·15) kg/m^2) than individuals without one. At the same time, those who lived in a census tract with a supercentre and a convenience store consumed fewer servings of fruits and vegetables (−1·22 (95 % CI −2·40, −0·04)).

Conclusions: The study contributes to a growing body of research aiming to understand how the food store environment is associated with weight and diet.

Keywords
Food
Environment
Perceived
Objective

The environment in which a person lives and works can facilitate or impede the accessibility, availability and affordability of healthy food[1]. These latter three variables, in turn, may influence individuals' weight and the quality of their diet[2–7]. Widespread recognition of the relationship between the built environment, health status and food choices has led to growing interest in measuring aspects of the food store environment[8–15]. However, few studies have examined both subjective[16,17] and objective measures of the food store environment and their association with weight and diet quality[7,17–22].

Perceived and objective measures each provide unique data that, taken together, can elucidate important factors operating at both the individual and the neighbourhood level. Subjective perceptions about food access and availability, for example, may shape individuals' food purchasing habits[23] and frequency of shopping[24]. Objective neighbourhood-level measures, such as in-store food audits or information on store type (collected on-site or from national databases), can supplement perceptual measures, documenting actual food availability in a given locality.

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Simultaneous consideration of both types of measure has the potential to establish a broader context for understanding the environmental determinants of obesity[16].

To date, there is little published research drawing on both objective and perceived measures to explore the relationship between individuals and their food store environment. Moreover, few studies have used both types of measure to examine associations between weight and fruit and vegetable intake[17]. Those studies that have assessed the food environment have found only limited associations among diet, weight status and the food environment[4,16]. In the USA, studies with an urban and suburban focus have suggested that lack of access to healthy foods in economically and socially disadvantaged neighbourhoods contributes to a lower intake of fruit and vegetables[25,26] and to a higher prevalence of obesity[27]. Outside the USA, however, studies have failed to detect any association between food environment and weight or diet quality[28–31].

To address existing gaps in knowledge, the present study was undertaken with both methodological and substantive aims. First, the study sought to highlight similarities and differences between subjective and objective measures of the food store environment at both the individual and the neighbourhood level. Second, the study examined associations between subjective/objective measures of the food store environment and (i) fruit and vegetable intake and (ii) weight status.

Methods

Study sample

Individual-level data were obtained from baseline surveys completed by women enrolled in a weight-loss intervention trial (Weight-Wise). Weight-Wise is an evidence-based behavioural weight-loss intervention shown to be effective in low-income women[32]. Participants (n 189) were women aged 40 to 64 years, with incomes at or below 250 % of the federal poverty level, and who had a BMI between 27·5 and 45·0 kg/m^2 inclusive. Women were recruited from six county health departments in North Carolina. Four of the six counties are classified as non-metro (less densely populated), while two are classified as metro[33] based on rural–urban continuum codes. Details regarding the study design, intervention components and baseline characteristics have been published elsewhere[32]. The University of North Carolina School of Medicine Institutional Review Board approved and monitored the study.

Food store environment

The study included two objective and two subjective food store environment indicators, measured at both the store and the neighbourhood level. At the store level, the food store environment was characterized by: (i) the availability of healthy foods in stores where Weight-Wise participants shopped, as measured by food store audits (objective); and (ii) summary scores of the women's self-reported perceptions of availability of healthy foods in their primary food store (perceived). At the neighbourhood level, measures of the food store environment included: (i) the number and type of food stores within the census tract (objective); and (ii) summary scores of the women's self-reported perceptions of availability of healthy foods in their neighbourhood (perceived). Each measure is described in greater detail below.

Objective measure of food availability at store level

Specific food stores where women shopped were identified from a survey question asking 'What is the name and street of the grocery store where you do your primary shopping?' The survey responses regarding the location of the named food store were confirmed using ground-truthing (direct observation of food store addresses)[1,34]. To ascertain in-store food availability, we modified items from the Nutrition Environment Measures Survey in Stores (NEMS-S)[35] using data about purchasing habits from the Bureau of Labor Statistics[36] and the US Department of Agriculture Continuing Survey of Food Intakes by Individuals (CSFII). To reflect the purchasing habits of the Weight-Wise study population (low-income southern women), we therefore added frozen and canned goods and pork, while excluding baked goods[37]. In the spring and summer of 2009 (after participants had been enrolled into the study), we assessed food availability in all eighty stores identified by participants, focusing on thirty-seven food items in nine food groups: (i) non-fat/low-fat milk; (ii) fruit; (iii) vegetables; (iv) low-fat meats; (v) frozen fruit and vegetables; (vi) canned vegetables; (vii) 100 % whole-wheat bread; and (ix) non-sugar-sweetened cereals. All stores were surveyed between 09.00 and 16.00 hours on weekdays to maintain consistency relative to stock on the shelves between stores. A tally sheet was used to determine whether the food item was available at the time of the audit. Each food item received 1 point if available, with a minimum possible survey score of zero and a maximum possible score of 37. Food store availability then was categorized as low, medium or high (tertiles) to facilitate comparisons with other studies[38].

Objective measure of food availability at neighbourhood level

We collected several types of data to measure neighbourhood food availability. First, data on the number and type of food stores in all six counties were obtained from InfoUSA, Inc. (Papillion, NE, USA) in August 2008 and 2009 to assure accuracy in addresses over repeated times. Food stores then were classified based on supplemented Standard Industrial Classification (SIC) codes to allow for comparisons with other studies[3,39]. Codes included supercentres (e.g. Super Walmart; SIC 531102), convenience

stores (SIC 541102, 541103), and supermarkets and large and small grocery stores (SIC 541101, 541104–541106). Second, to assess the number of stores in each participant's neighbourhood, home addresses were geocoded and matched to the 2000 US census tracts using Juice analytics software (http://www.juiceanalytics.com) and ArcMap (ArcGIS version 9·2, 1999–2994; ESRI, Redlands, CA, USA). Finally, the objective neighbourhood availability variable was dichotomized as either 'yes' (≥1 store) for each store type in the census tract or 'no' (none of that store type)[3].

Measure of perceived healthy food availability and accessibility in neighbourhoods and primary food stores

Participants' self-report of their local food environment was collected via a telephone survey after enrolment into Weight-Wise but before the intervention began. The survey questions were used to measure perceived access to and availability of healthy foods in each woman's neighbourhood (defined as the area approximately 5 miles around her home), as well as availability in her primary food store (described in detail below).

Neighbourhood healthy food availability

To assess perceived neighbourhood healthy food availability, participants were asked about the extent to which they agreed with the following statements about their neighbourhood: (i) 'A large selection of fruits and vegetables is available in my neighbourhood'; (ii) 'A large selection of low-fat products is available in my neighbourhood'; and (iii) 'The fruits and vegetables in my neighbourhood are of a high quality'. Responses to all questions were coded on a 5-point Likert scale (0 = 'strongly agree'; 4 = 'strongly disagree'). The neighbourhood availability questions have previously been tested for reliability and validity and are described elsewhere[4,40].

In-store healthy food availability

Participants were also asked about the extent to which they agreed with the following statements for their primary food store: (i) 'A large selection of fruits and vegetables is available'; (ii) 'A large selection of low-fat meat products is available (90 % lean beef, skinless chicken)'; (iii) 'A large selection of brown breads is available'; and (iv) 'A large selection of low-fat cheese or skim milk is available'. Responses to all questions were coded on a 5-point Likert scale (0 = 'strongly agree'; 4 = 'strongly disagree'). The total possible score on this measure was 0 to 16, with a higher score indicating higher perceived availability. The food store availability questions were adapted from the neighbourhood questions, after being pre-tested among ten low-income women in a rural community in North Carolina.

Responses from both neighbourhood questions and food store questions were summed into two separate summary scores (neighbourhood availability and food store availability) and then categorized into high, medium and low availability (tertiles) based on distribution of data.

Accessibility

Access was defined in two ways: (i) objective potential spatial access (network distance along roads from participant's home to primary food store); and (ii) perceived access (length of time and distance travelled to primary food store). A dichotomous variable was created to group access into easy or difficult access based on bimodal distribution of data. Easy access was defined as living <5 miles or <10 min travel time to the primary food store *v.* difficult access as ≥5 miles or ≥10 min to the primary food store. The cut-off points of 5 miles or 10 min correspond approximately to the mean response, and are also consistent with the cut-off points used in previous studies[18].

Definition of outcomes

BMI and weight

At the beginning of the intervention, participants were weighed to the nearest 0·5 lb (1 lb = 0·4536 kg) on an electronic scale (Seca 770; Seca Corporation, Columbia, MD, USA). Weight was measured twice and the average of the two measurements was used as the final weight. Height was measured with a portable stadiometer (Schorr Productions, Olney, MD, USA). Both height and weight were measured according to approved protocols[32]. BMI was calculated as kg/m^2.

Fruit and vegetable intake

Fruit and vegetable intake was collected using a validated rapid food survey[41] which assessed fruit, vegetable and fibre intakes. The survey is effective in identifying persons with high fat intake, low fruit/vegetable intake or low fibre intake. The fruit and vegetable servings per day were determined from the food survey.

Statistical analysis

Of the 189 women originally enrolled in the intervention, three women were missing all exposure variables on perceived access and were excluded from analyses, leaving a total sample of 186 women for analysis. There were no significant differences on key outcome or exposure variables between the total sample and the missing women. All was analyses were conducted using the STATA statistical software package version 11·0 (StataCorp., College Station, TX, USA).

To estimate the associations between perceived and objective neighbourhood availability, logistic regression with robust standard errors, utilizing White–Huber correction to account for county-level clustering, was used. In relevant models where census tract was the exposure variable, no stores in a participant's census track was used as the referent category. Additionally, models were stratified by store type or by combination of store type based

on a priori hypothesis and direct field observation of community landscape.

Multinomial (polytomous) logistic models were used to analyse the three-level categorical outcome of perceived food store availability for the three-level exposure variable of objective food store availability. In all cases, low perception or low objective food store availability was used as the reference category.

Multivariable linear regression was used to model the association among fruit and vegetable intake, weight, BMI, and perceived or objective measures of the food store environment.

All associations were adjusted in all models for race (black, white, other), education (years of education completed), income (reported range of household income such as $US 20 000–29 999) and smoking status (excluded when fruit and vegetable intake was modelled as outcome). All models included a cluster statement on county since women are nested within the six counties, allowing for robust standard errors. The type I error rate was set at 0·05 for main effects. The inclusion of a random intercept for census tract or store was not warranted (intra-class correlation coefficient of 0·001).

Results

The study sample consisted of 186 women with complete data on all variables. Descriptive statistics for subjective and objective measures of the food store environment and shopping habits are shown in Table 1.

Table 2 shows the association between living in a neighbourhood with each type of food store and the odds of perceiving the neighbourhood as high in availability of healthy foods. Individuals who lived in census tracts with at least one convenience store and one supercentre had higher odds of perceiving their neighbourhood as high in availability of healthy foods (OR = 6·87 (95 % CI 2·61, 18·01)) than individuals who did not have any stores in their neighbourhood. Interestingly, our study did not find those who lived in areas with a high density of supermarkets perceived their neighbourhood to have many healthy food items.

Table 3 displays the results for prevalence ratios and predicted probabilities between perceived and objective food store availability. As the number of healthy foods available in a store decreased in objective terms, the probability that participants would perceive the store to have a high availability of healthy foods increased.

Strongly agreeing that the neighbourhood and store had many healthy foods, as indicated by perceived food store environment responses (Table 4), was not associated with any of the outcomes.

Objective food store environment results (Table 5) indicate that individuals with a supercentre in their census tract weighed more (2·40 (95 % CI 0·66, 4·15) kg/m^2, $P = 0·02$; 14·72 (95 % CI 4·32, 25·11) lb, $P = 0·02$) compared with individuals without one. Individuals who lived in a census tract with a supercentre and a convenience store also consumed fewer servings of fruits and vegetables (−1·22 (95 % CI −2·40, −0·04), $P = 0·04$).

Table 1 Perceived and objective measures of the food store environment, outcome measures, shopping habits and demographics, North Carolina, 2009 (*n* 186)

	Mean or %	SD
Perceived neighbourhood availability*		
(range 0–12)	8·2	3·1
Perceived food store availability*		
All foods (range 0–16)	12·6	2·4
Perceived access†		
Distance in miles	5·5	5·9
Objective neighbourhood availability*		
Supercentres	0·2	0·4
Supermarkets	2·3	2·3
Convenience stores	2·3	2·0
Objective food store availability*		
Food store score (range 0–37)	34·3	3·6
Objective access†		
Distance in miles	6·1	6·4
Outcome measures		
BMI (kg/m^2)	37·0	4·7
Weight (lb)‡	219	30·8
Fruit and vegetable servings (range 0·41–8·47)	4	1·7
Fruit and vegetable score (range 1–25)	13	4·6
Frequency of shopping (%)		
1 time per week	22	
2 to 3 times per month	23	
1 time per month	8	
Demographics		
Age (years)	51	7·4
Smoking (%)	15	
Education (years)	13	1·9
Employed full time (%)	32	
Income ≤$US 29 000 (%)	69	

*Higher score indicates greater availability at the store and neighbourhood level of healthy foods.
†Access is reported or calculated miles from home to primary food store.
‡1 lb = 0·4536 kg.

Table 2 Odds ratio and 95 % confidence interval for perceived availability of healthy foods by type of store in census tracts, North Carolina, 2009 (*n* 186)

	Perceived neighbourhood availability	
	OR	95 % CI
All stores in census tract*		
Low density (reference)	1·00	
Medium density	1·10	0·42, 2·89
High density	2·09	0·69, 6·29
Store type in census tract		
No store by type (reference)	1·00	
Supermarket	0·77	0·23, 2·59
Supercentre	3·76	0·96, 14·62
Convenience	1·66	0·59, 4·64
Store combination in census tract		
No store by type (reference)	1·00	
Convenience and supercentre	6·87	2·61, 18·01
Supercentre and supermarket	3·41	0·43, 27·23

All models adjusted for race, education, income and age.
*Low density, <2 stores in census tract; medium density, 2–7 stores in census tract; high density, >7 stores in census tract.

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Table 3 Prevalence ratio (PR) with 95 % confidence interval and predicated probability of perceived and objective food store availability of healthy foods, North Carolina, 2009 (*n* 186)

All stores combined	PR	95 % CI	Predicted probability
Medium perceived food store availability			
High objective food store availability	0·11	0·01, 0·86	0·54
Medium objective food store availability	0·40	0·05, 3·23	0·63
Low objective food store availability (reference)	1·00		0·65
High perceived food store availability			
High objective food store availability	0·09	0·01, 0·67	0·22
Medium objective food store availability	0·30	0·04, 2·12	0·28
Low objective food store availability (reference)	1·00		0·32

All models adjusted for age, race, education and income.

Table 4 Perceived local food environment and the association with diet and weight, North Carolina, 2009 (*n* 186)

	Outcome					
	BMI (kg/m^2)		Weight (lb)*		Fruit/vegetable servings	
	β	95 % CI	β	95 % CI	β	95 % CI
Food store access†	−0·83	−2·39, 0·73	−1·52	−11·13, 8·08	0·14	−0·34, 0·66
Neighbourhood availability of healthy foods‡						
Low availability	Reference		Reference		Reference	
Medium availability	−0·92	−3·76, 1·92	−5·64	−27·45, 16·15	0·70	−1·36, 2·77
High availability	−0·28	−3·45, 2·90	−1·81	−23·79, 20·18	0·52	−1·03, 2·08
Food store availability of healthy foods§						
Low availability	Reference		Reference		Reference	
Medium availability	1·04	−0·50, 2·59	3·09	−4·61, 10·80	−0·44	−0·93, 0·05
High availability	1·22	−0·22, 2·67	5·49	−4·42, 15·40	0·25	−0·29, 0·78

Each block represents the coefficient for one separate model. All models adjusted for race, age, education, income and smoking status (latter excluded when fruit and vegetable intake was modelled as outcome).
*1 lb = 0·4536 kg.
†Easy access is defined as <5 miles as first inclusion followed by <10 min travel time. R^2 values 0·04–0·07.
‡Neighbourhood availability: low, ≤4; medium, 4–8; high, >8; range 0–12. R^2 values 0·04–0·07.
§Store availability: low, ≤10; medium, 10–14; high, >14; range 6–16. R^2 values 0·04–0·09.

Table 5 Objective food store environment and the association with weight and diet, North Carolina, 2009 (*n* 186)

	Outcome					
	BMI (kg/m^2)		Weight (lb)*		Fruit/vegetable servings	
	β	95 % CI	β	95 % CI	β	95 % CI
Store type						
No store by type	Reference		Reference		Reference	
Supercentre	2·40 (P = 0·02)	0·66, 4·15	14·72 (P = 0·02)	4·32, 25·11	−0·34	−1·23, 0·55
Supermarket	1·47	−1·23, 4·16	5·18	−8·14, 18·49	0·12	−0·62, 0·86
Convenience store	0·21	−1·46, 1·88	2·03	−11·39, 15·46	−0·76	−1·59, 0·07
Supercentre and convenience	2·64	0·02, 5·25	17·86	−1·21, 36·93	−1·22 (P = 0·04)	−2·40, −0·04
Supercentre and supermarket	2·96	−0·76, 6·69	15·07	−7·78, 37·93	−0·16	−1·75, 1·42
Supermarket and convenience	2·22	−0·74, 3·69	3·27	−6·21, 12·75	−0·19	−0·71, 0·33
Access to food store†						
Easy access	Reference		Reference		Reference	
Difficult access	−0·11	−1·95, 1·73	−0·12	−13·75, 13·50	0·10	−0·39, 0·59
Food store availability of healthy foods‡						
Low availability	Reference		Reference		Reference	
Medium availability	0·65	−3·03, 4·34	5·71	−17·06, 28·48	0·67	−0·75, 2·09
High availability	1·13	−2·34, 4·47	8·89	−4·79, 22·56	0·73	−0·77, 2·23

Interaction terms significant at $P \leq 0·05$. Each block represents the coefficient for one separate model. All models adjusted for race, age, education, income and smoking status (latter excluded when fruit and vegetable intake was modelled as outcome). R^2 values 0·04–0·18.
*1 lb = 0·4536 kg.
†Easy access is defined as <5 miles or <10 min travel time, difficult access as ≥5 miles or ≥10 min travel time.
‡Food availability: low, <30 points; medium, 30–35 points; high, >35; range 9–37 points.

Discussion

The present study highlights how subjective and objective measures can provide insight into cross-sectional associations between food store environment, weight, and fruit and vegetable intake. Our study presents conflicting results when comparing subjective and objective measures at the store and neighbourhood levels, while

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pointing to an association between objective (but not subjective) food store environment measures with weight and fruit and vegetable intake.

Our first set of results examined the odds of perceiving a neighbourhood as having healthy food items depending on what stores were available. Our study did not find an association for those who live in areas with a high density of supermarkets perceiving their neighbourhood to have many healthy items. This is not consistent with other studies and a bit surprising[39,42]. However, this result may reflect variation in the quality of healthy food items available for purchase in rural supermarkets relative to urban supermarkets, where most of the studies have taken place. For example, although a neighbourhood may have many supermarkets, the actual quality of the food available for purchase may be low and thus individuals in those neighbourhoods perceive the healthy food items to be of low quality. We then found that individuals who live in neighbourhoods with supercentres and convenience stores are more likely to perceive their neighbourhood as high in availability of healthy food items compared with those living in a neighbourhood with no stores. This finding suggests that having multiple food store options, relative to no stores within the census tract, influences perceptions at the neighbourhood level[43].

The second set of results compared perceived and objective measures within the stores where individuals shop. Surprisingly, women who shopped at a grocery store with many healthy foods actually had a lower probability of perceiving their food store as high in availability. One possible explanation for this discrepancy between perceived and actual availability at the store level is that perceived quality, not assessed in our study, may contribute significantly to perceived availability[41]. Without an assessment of quality, our objective measure of availability may not have fully captured the foods most likely to be perceived as acceptable for purchase.

Our next set of results used both types of measure to examine the association of food store environment with fruit and vegetable intake and weight. Although we found no associations of the two outcomes with perceptions of the store or neighbourhood, objective measures of the food store environment were associated with weight and diet. Individuals residing in neighbourhoods with supercentres had a higher BMI and lower consumption of fruits and vegetables. Although supercentres in and of themselves may not be directly responsible for increased weight, our findings suggest that supercentres are likely to be markers of neighbourhoods that have other characteristics associated with an 'obesogenic' environment. For example, rural landscapes or 'food swamps' may be more conducive to the building of superstores[44], and may also have a higher density of fast-food restaurants and fewer areas for recreation and physical activity[44–46].

Our study has several limitations. First, objective food store addresses were collected from secondary data sources, which may misrepresent the true number of food stores currently available to residents[1,34]. Second, the use of census tracts to define neighbourhoods may not reflect individuals' true neighbourhood habits and exposure level. Third, our study captured only three types of food store, whereas the food store environment may comprise many other non-traditional food outlets (e.g. Dollar Stores)[1]. Fourth, because our study sample consisted only of low-income overweight women, our ability to generalize to other populations is limited. Finally, perception-based measures may be subject to measurement error and may be influenced by differing cultural, economic and neighbourhood contexts[16].

Conclusions

The present study contributes to a growing body of research seeking to understand whether and how the food store environment is associated with weight and diet, especially among low-income and rural residents[1,9,10]. Our results, which point to discrepancies between perceived and objective measures of the food store environment, confirm the importance of obtaining both types of measure to deepen our awareness of the food environment and its influence on obesity risk. Additional research is needed to disentangle the respective influence of individual- and neighbourhood-level food environment factors on diet and weight status.

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