

Fruit and vegetable availability: a micro environmental mediating variable?

Russell Jago^{1,*}, Tom Baranowski² and Janice C Baranowski²

¹Department of Exercise, Nutrition and Health Sciences, Centre for Exercise & Health, University of Bristol, Tyndall Avenue, Bristol BS8 1TP, UK; ²Children's Nutrition Research Center, Department of Pediatrics, Baylor College of Medicine, 1100 Bates Street, Houston, TX 77030, USA

Submitted 22 March 2006: Accepted 31 October 2006: First published online 20 February 2007

Abstract

Objectives: To examine the association between fruit and vegetable (F&V) availability and consumption, the possible influences on this association, research gaps, and implications for developing strategies to increase F&V consumption.

Design: Systematic review of studies that have examined associations between F&V availability and consumption.

Results: Qualitative studies conducted among children and adults indicated that greater availability was associated with greater consumption. This finding was supported by cross-sectional studies among children. Availability was associated with dietary psychosocial variables such as preferences, and it appears that availability may moderate the relationship between these psychosocial variables and consumption. Intervention studies attempting to increase availability have resulted in increased consumption, and availability has predicted change in consumption over an 18-month period.

Discussion: Availability appears to be a key proximal determinant of consumption, especially of F&V, and thereby provides a target for change. However, the mechanisms that relate these variables are unclear and there is a need to clarify the direction of causality. We suggest that the possible causal mechanisms may include: (1) availability simply facilitates increased consumption; (2) the visual cues of available food may stimulate consumption; and (3) available food exposure may increase preference, which leads to increased consumption. Each of these possibilities requires close examination, as do policy-level interventions.

Conclusion: F&V availability is associated with increased consumption. Research that elucidates the mechanisms between availability and intake, and tests policy-level interventions, is needed to advance increased availability as a public health procedure.

Keywords
Consumption
Mediators
Review
Policy

Regular consumption of fruit and vegetables (F&V) has been associated with a decreased risk of developing many forms of cancer¹ and coronary heart disease². Yet despite these well-established health benefits, both children³ and adults⁴ in the USA and many other Western countries, such as the UK^{5,6}, are not meeting national guidelines for F&V consumption. Consequently there is a need to develop effective local, regional and national strategies to increase F&V consumption.

The mediating variable model suggests that changes in a behaviour are a function of changes in the variables that directly impact the behaviour^{7,8}. Thus, in order to change F&V consumption the factors that impact F&V consumption need to be changed. While many variables such as preferences⁹ and self-efficacy¹⁰ have been associated with F&V consumption, perhaps the strongest predictor has

been home availability^{9,11,12}. Home availability of F&V is particularly interesting because of its proximal nature to consumption. Availability should be reasonably easy to manipulate and small changes in availability may yield changes in consumption that could provide important health benefits.

The model of home food management processes proposed by Campbell and Desjardins¹³ indicates that food consumption is influenced by a series of hierarchical and interlinked processes that begin with the wider environment, move through household resources (F&V can only be purchased if there is sufficient money), family provision strategies for food, food acquisition (where the F&V are purchased), food supply management (how the food is stored, i.e. fresh, frozen or canned), food preparation techniques (how the food is prepared,

*Corresponding author: Email Russ.Jago@bris.ac.uk

i.e. steamed or deep fried) and end in consumption. Thus home availability plays a central role in this model, which highlights that F&V are only consumed if purchased, stored and prepared. In order to impact consumption, the food needs to be 'available' to eat.

Different studies have interpreted 'availability' in slightly different ways¹⁴. US investigators have interpreted availability as the presence of foods in an environment, while Norwegian researchers have included availability items (such as the presence of F&V in the fridge) in an accessibility measure. This difference can be confusing, as US researchers interpret accessibility as not just whether a food is available in the home but whether it is in a form, location and time that makes consumption easy¹⁵. In earlier public health research alcohol and tobacco availability measures assessed the extent to which these two drugs could be obtained from different sources such as vending machines and stores¹⁶. Extrapolation suggests that availability should address the extent to which F&V are available in a defined location. Consequently, we adopted the definition of Cullen and colleagues¹⁵ that 'availability concerns whether foods of interest (fruit and vegetables) are present in an environment' (p. 616) such as in the home, school or work cafeteria. With this definition in mind the aims of the present paper are to: (1) illustrate associations between food availability and consumption; (2) highlight how increasing availability has been used to increase consumption; (3) propose the mechanisms by which availability is associated with consumption; and (4) highlight the areas in which further research is required.

Methods

A literature search was conducted for studies examining F&V availability and consumption. Computerised searches of PubMed and PsycINFO were conducted in December 2005 using 'availability, accessibility, fruit and vegetables' as keywords. These searches were supplemented by additional follow-up manual searches and examination of the authors' extensive personal records. All of the papers were reviewed to ensure that articles assessed aspects of F&V availability. Articles that met this criterion were summarised and placed into tables that were grouped by study design.

Results

Qualitative studies

Studies that included qualitative reports of associations between F&V availability and intake are summarised in Table 1^{17–24}. Home F&V availability was perceived to be associated with intake among 4th–6th grade children^{17,21}. Similar perceptions were reported among 7th and 10th grade students in relation to healthy foods (including F&V)²⁰. Among Native American adults, qualitative research showed that the limited availability of fresh F&V on the reservation was perceived to hinder consumption²². The availability of F&V also appears to be influenced by broader social and demographic characteristics. Although F&V were available in most children's homes, the degree of availability differed by socio-economic status (SES) but not ethnicity^{18,19,21}. Children from higher-income homes were more likely to

Table 1 Qualitative studies reporting availability influencing fruit and vegetable (F&V) consumption

Authors	Study design	Key finding
Baranowski <i>et al.</i> (1993) ¹⁷	Focus groups with 4th and 5th grade students	Increasing availability of F&V was suggested as a means of increasing intake
Kirby <i>et al.</i> (1995) ¹⁸	Focus groups with 4th/5th grade students, parents, teachers and school food service workers	Availability of F&V differed by SES
Cullen <i>et al.</i> (1998) ¹⁹	Focus groups with urban boy scouts and parents	F&V freely available in home, but not sold as alternative items at school lunch
Neumark-Sztainer <i>et al.</i> (1999) ²⁰	Focus groups with 7th and 10th grade students	Availability associated with consumption and participants suggested increasing availability may increase consumption
Cullen <i>et al.</i> (2000) ²¹	Focus groups with 4th–6th grade children and parents from Mexican-American, African-American and Euro-American schools	Both parents and children reported that availability of F&V influenced consumption
Vastine <i>et al.</i> (2005) ²²	Interviews to assess food-purchasing patterns among Native Americans	Lack of fresh food on the reservation, particularly F&V, hindered consumption. Participants suggested that increasing availability on the reservation would aid consumption
Molaison <i>et al.</i> (2005) ²³	Focus groups with 42 low-income, 10- to 13-year-old African-Americans to understand influences on F&V consumption	F&V availability reported as influencing consumption
Wind <i>et al.</i> (2005) ²⁴	Focus groups with 92 10–11-year-old Belgian and Dutch children to understand factors associated with consumption	Availability of F&V was low at home and at school, and this appeared to influence intake

SES – socio-economic status.

have a greater variety of fresh F&V available while children from lower-income homes were likely to have less choice and more canned and frozen foods¹⁸. The types of foods available were also different in urban and rural homes¹⁸. Children reported that F&V were not sold as alternative items during school lunch, and hence their lack of availability at this location likely hindered consumption¹⁹. Collectively these studies provide qualitative support for an association between F&V availability and consumption, but suggest that availability may be affected by broader sociodemographic characteristics such as income and location (urban, rural or reservation).

Cross-sectional studies

Cross-sectional assessments of F&V availability are summarised in Table 2^{25–32}. Hearn and colleagues first reported a positive association between home availability and consumption among 3rd grade students²⁵. The same study also showed that the availability of F&V at school lunch predicted intake at this specific eating venue. Further, although home availability did not differ by SES or

ethnicity, schools that provided a higher number of subsidised lunches (an indicator of SES) tended to offer fewer servings of fruit²⁵. F&V availability also predicted intake among 218 low-income mothers²⁶. Thus, these studies and the qualitative research (above) suggest that the associations among availability at home and school and SES are not clear and more research is needed in this area.

Home availability of F&V was associated with self-reported intake among girls, but not boys^{15,29}. The cause of this gender discrepancy is not clear, but the results suggest that targeting increased availability may be less likely to be effective at increasing the consumption of boys and therefore gender-specific strategies may be necessary. A recent study has reported that parent-reported home availability was associated with fruit intake among white adolescents but not among African-American adolescents, while vegetable availability was not associated with intake in either ethnic group³². This finding conflicts with the earlier qualitative work and suggests that further examination of ethnic differences is also warranted.

Table 2 Quantitative studies reporting associations between availability of fruit and vegetables (F&V) and consumption

Authors	Study design	Key findings
Hearn <i>et al.</i> (1998) ²⁵	Study 1: F&V consumption obtained from 3rd grade children via a food diary and parental report of home availability/accessibility	Study 1: Home availability/accessibility (combined measure) predicted consumption but did not differ by ethnicity, SES or parental marriage status
Quan <i>et al.</i> (2000) ²⁶	Study 2: F&V consumption at lunch & staff assessment Quantitative interview of 218 low-income mothers and the factors influencing vegetable consumption	Study 2: Availability of F&V at school lunch was associated with consumption Home availability of F&V predicted intake
Kratt <i>et al.</i> (2000) ²⁷	Self-reported F&V consumption of 1625 4th grade students. Parental report of availability. Child measures of F&V self-efficacy, knowledge & outcome expectancies	Consumption of F&V, knowledge and self-efficacy of children and parents increased as availability increased
Cullen <i>et al.</i> (2003) ¹⁵	Self-reported F&V consumption by 225 5th–6th grade students using food records. Child- and parent-reported availability	F&V availability predicted consumption, accounting for 10% of the variance. Association between availability and intake moderated by preferences
Neumark-Sztainer <i>et al.</i> (2003) ¹²	Self-reported F&V intake of among 3957 middle-school students and associations with availability, preferences, attitudes, meal patterns and SES	Availability was strongest predictor of F&V intake. Relationships between social support, meal patterns, food security, SES and F&V intake were moderated by availability
Bere and Klepp (2004) ¹¹	Assessment of correlates of 1950 6th and 7th grade children's F&V consumption	A measure that included availability items was correlated with intake
Young <i>et al.</i> (2004) ²⁸	Self-reported F&V consumption of 366 middle-school students. Child-reported parenting style, parental control, parental modelling, availability and self-efficacy	Availability was the strongest ($r = 0.525$) correlate of F&V consumption. Association between parental modelling and F&V intake moderated by availability
Hanson <i>et al.</i> (2005) ²⁹	Cross-sectional assessment of middle-school students' dietary intake	Home availability of F&V was associated with intake among girls but not boys
Baranowski <i>et al.</i> (2006) ³⁰	Validation of adult F&V outcome expectancies scales and home availability	Outcome expectancy scales correlated ($r = 0.18$ to 0.33) with home availability
Baranowski <i>et al.</i> (2006) ³¹	Validation of home pantry management practices and home availability scales	Home pantry management practices correlated with home availability ($r = 0.23$ to 0.37)
Befort <i>et al.</i> (2006) ³²	Assessment of correlates of F&V intake among African-American and Euro-American adolescents (0–19 years of age)	Fruit availability was associated with intake but only among the Euro-American participants. No association between vegetable availability and intake among either group

SES – socio-economic status.

Home F&V availability has been associated with psychosocial predictors of intake. Among 4th grade students participating in the High 5 Alabama programme, mean consumption of F&V increased with availability, as did knowledge about F&V and F&V self-efficacy²⁷. Since knowledge and self-efficacy were strong predictors of intake in homes with high availability but not low availability, availability appears to have moderated the associations between self-efficacy, knowledge and F&V intake²⁷. Availability was the strongest predictor of F&V intake among middle-school students and was also associated with parental control, parental modelling, parental support and self-efficacy²⁸. The association between parental modelling and support of F&V consumption and childhood intake was moderated by home availability. Thus, parents were more likely to consume F&V and encourage their children to do so if F&V were available in the home. These two studies demonstrate that availability is not only associated with intake, but it also moderates the association between other psychosocial variables and intake. Home availability of F&V is therefore both directly and indirectly associated with children's consumption.

One of the most consistent psychosocial predictors of F&V intake has been preferences^{9,33}, but the association between preferences and availability was not clear. Among 225 5th and 6th grade students, availability alone was a significant predictor in a model that accounted for 11% of the variance in F&V intake among participants with high preferences for F&V¹⁵. However, among those with low preferences, both availability and accessibility were significant predictors in a model that accounted for 23% of the variance. Thus, the association between intake and

availability was moderated by preferences. F&V availability was associated with taste preferences among middle-school students¹²; when availability was low intake did not differ by preferences, but when preferences were low, intake increased among all groups if F&V were available. Thus, while both studies support associations between preferences, intake and availability, the nature of the relationships is not clear and requires further clarification.

Cross-sectional associations between dietary fat availability and intake

Support for the association between availability and intake was provided by similar findings in relation to the availability and consumption of dietary fat. In a random digital dial survey the presence of high-fat foods in the pantry correlated with the percentage of energy consumed from fat³⁴. A similar observation was reported among North American Chinese women³⁵. Interestingly, the availability of high-fat foods was associated with both intake and preferences, and preferences moderated the relationship between availability and intake³⁶. These studies therefore provide support for the findings of Cullen *et al.*¹⁵ and suggest that further examination of these two key variables and their interaction to predict intake of foods is warranted.

Associations between grocery store and restaurant availability and consumption

Studies that assessed associations between grocery store or restaurant F&V availability and intake are summarised in Table 3^{37–41}. In a qualitative study of participants residing in a Scottish Island community, the availability of fresh

Table 3 Studies reporting restaurant and grocery store fruit and vegetable (F&V) availability and consumption

Authors	Study design	Findings
McKie <i>et al.</i> (1998) ³⁷	Focus groups of provision of foods in a Scottish island community	Participants reported that F&V were scarcely available, poor in quality and expensive. Respondents reported that this was a major factor in poor diet choices
Naska <i>et al.</i> (2000) ³⁸	Assessed national-level availability of F&V in 10 European countries and estimates of consumption	Disparity across countries in availability and intake
Edmonds <i>et al.</i> (2001) ³⁹	Cross-sectional survey of FJV intake of 90 African-American boy scouts and audit of randomly selected restaurants and grocery stores in the census tracts in which participants resided	Restaurant fruit juice availability associated with child's juice consumption. Suggestive association between restaurant vegetable consumption and child vegetable consumption
Cummins and Macintyre (2002) ⁴⁰	Analysed the availability of 57 foods adequate for diet in Glasgow and differences by deprivation area	Orange juice and tinned tomatoes were less available in lower-income postcodes than in higher-income places
Rose and Richards (2004) ⁴¹	Secondary analysis of national Food Stamp Program. Looked at household F&V use and associated with distance to the nearest supermarket	Distance from home to supermarket was inversely related with F&V intake. Participants living > 5 miles from supermarket consumed an average of 62 g of fruit less than those residing closer to store (approx. 1 serving per day). Similar finding for vegetables with 36 g per person per day increase, approx. 0.5 servings per day

FJV – fruit, juice and vegetables.

F&V in this extreme location was limited; the foods were expensive and of poor quality; and the participants felt that limited availability was a major factor in their consumption of an undesirable diet³⁷. Availability of fruit, juice and vegetables at restaurants in the census tract within which boy scouts resided was associated with fruit, juice and vegetable consumption³⁹. Since Scottish researchers have shown that foods such as orange juice and tinned tomatoes were less available in lower-income postcodes than higher-income places⁴⁰, it is possible that census tract differences are a function of SES. Alternatively, it is possible that differences could be a function of broader environmental features such as location and town planning. This hypothesis is supported by a secondary analysis of the US national Food Stamp Program, in which the distance to the nearest supermarket was inversely associated with F&V intake⁴¹. Participants who lived more than 5 miles from the nearest supermarket consumed 62 g of fruit and 36 g of vegetables per day less than those residing closer to the store. This equated to approximately 1 serving of fruit and half a serving of vegetables, and thus greater distance was associated with a combined 1.5 fewer servings per day. It is important to note that the association between the availability of F&V in the local neighbourhood and consumption is consistent with the hierarchical model of Campbell and Desjardins¹³ and provides support for wider environmental features influencing home

availability which in turn influences consumption. However, the pathways from local environment availability to home availability to consumption still need to be elucidated.

Intervention studies

Studies that have either examined how to modify availability to increase consumption or conducted interventions that have focused on increasing availability are summarised in Table 4^{17,33,42–46}. Focus groups conducted with 4th and 5th grade students and teachers¹⁷ indicated that children influence the types and amounts of F&V that parents purchase and keep within the home, and thus enhancing children's ability to ask for F&V (in a polite manner at an appropriate time) may result in increased availability.

Incorporating the development of asking skills (via role play) into an intervention for elementary-school children resulted in a significant 0.2 serving difference in the F&V intake of intervention over control schools^{42,43}. Parental interviews also indicated that F&V home availability increased as a function of participating in the intervention⁴³. Although the small increase in F&V servings and the relatively small number of schools in the study (the school was the unit of analysis) prevented a mediation analysis, it seems likely that the change in availability mediated the effect of this intervention. A similar finding was reported in

Table 4 Fruit and vegetable (F&V) intervention and longitudinal studies

Authors	Study design	Findings
Baranowski <i>et al.</i> (1993) ¹⁷	Focus groups among 4th and 5th grade students to understand factors influencing F&V consumption	Type and amount of foods purchased by parents influenced by requests from children, so increasing children's ability to ask for healthy foods such as F&V may increase home availability
Baranowski <i>et al.</i> (2000) ⁴²	GIMME 5 intervention which was designed to increase F&V consumption of elementary-school children. Intervention included the development of asking skills for F&V (to increase home availability) via role play	Intervention resulted in 0.2 serving increase in daily F&V consumption of participants
Davis <i>et al.</i> (2000) ⁴³	Process evaluation of the GIMME 5 intervention	Significant treatment by year interaction for fruit availability suggesting that the intervention (see above) effect could have been mediated by changes home availability
Baranowski <i>et al.</i> (2002) ⁴⁴	Intervention to increase F&V consumption of urban boy scouts via intervention that included the development of asking skills to increase availability	Increase of 0.8 serving in daily F&V intake. Significant increase in home availability of F&V
Perry <i>et al.</i> (2004) ⁴⁵	Evaluation of a school-based intervention to increase F&V consumption of elementary-school children via increased availability, events and challenges	0.14 serving per day difference in F&V consumption between intervention and control schools at the end of the study and availability was associated with consumption at baseline and post-test (no mediation effects)
Bere and Klepp (2005) ³³	Baseline and 18-month follow-up of 816 11-year-old Norwegian children and associations with combined availability and accessibility measure	Availability predicted intake at both time points. Changes in availability correlated with changes in intake
Bere <i>et al.</i> (2006) ⁴⁶	Evaluation of policy-level intervention that included classroom activities, parental information and participation in Norwegian School Fruit Programme	Although schools and students engaged in programme and participated in school fruit programme, no significant intervention effect. Authors suggest this could be due to a failure to change availability

a subsequent intervention that focused on developing asking skills among urban boy scouts, which resulted in a 0.8 serving increase in F&V intake⁴⁴. The study also reported a significant intervention effect for home availability, suggesting that home availability mediated change in F&V intake among adolescents. Finally, the authors of a recent Norwegian study⁴⁶ that attempted to increase availability via a curriculum and parent intervention in part attributed their failure to impact consumption to an inability to change home F&V availability.

Longitudinal association

Longitudinal support for the association between the availability of F&V and intake was obtained from a study (Table 4) which showed that a measure including F&V availability predicted intake at baseline and 18 months later³³. The study also found that changes in home and school availability and accessibility (combined measures) correlated with changes in intake and that baseline availability moderated the relationship between change in F&V preferences and intake. Thus, the associations between availability and intake were maintained over time, availability functioned as a mediator of change, and the interactions between preferences and availability were important in understanding and developing strategies to change children's F&V consumption.

Influences on home availability

A recent study of adult food shoppers showed that three measures of the perceived benefits of purchasing F&V (outcome expectancies) were correlated with home F&V availability³⁰. Measures of social support³¹, pantry management practices³¹ and outcome expectancies³⁰ were also correlated with home F&V availability. Frequent food shopping would enable fresh F&V to be readily available within the home, while less frequent shopping is likely to result in either less fresh F&V or more canned and frozen F&V⁴⁷. The most common food shopping pattern was one big weekly trip to the grocery store with a few additional small trips. However, while 35% of the participants adopted this pattern, a small but potentially very important 8% of participants shopped once a month, while 6% only shopped biweekly⁴⁷. While no significant socio-economic differences were found for overall frequency of food shopping, lower-income respondents were more likely to obtain F&V from convenience stores while higher-income participants were more likely to purchase F&V from restaurants for home consumption. These findings suggest that strategies to increase home availability of F&V could be tailored based on home food management practices. An improved understanding of purchasing patterns and associations with the availability for different types of F&V, as well as participants' preferences for canned, fresh or frozen foods, would facilitate this tailoring as it would allow messages to be created that focus on increasing the availability of the

foods that families are more likely to purchase. This improved understanding could also be used to further develop children's asking skills by either developing techniques to encourage their parents to purchase more fresh F&V (i.e. change their shopping practices) or by encouraging their parents to purchase more canned or frozen foods.

Discussion

This review demonstrated that the home availability of F&V was associated with intake among children, adolescents and adults, and the association between intake and consumption was maintained over time. The association between availability and intake was complex and likely to differ by demographic and psychosocial variables. A greater understanding of the mechanisms by which availability may impact consumption would aid the design of more effective programmes that attempt to increase consumption via availability.

A key research issue is to clarify the direction of causality. Do children eat more F&V because they are available, or do parents make F&V available because they know their children will eat them? This issue could be addressed by simply providing F&V to families, assessing what happens to them (e.g. consumed by whom or left spoiled) and evaluating the overall diet (e.g. whether family members eat less other F&V to compensate for the free food). The issue of the role of preferences could be addressed by systematically varying the F&V offered to reflect those known to be preferred by the child. Addressing the causality issue will determine whether home availability should be included as a mediating variable in intervention studies.

While there are many factors that could explain the association between availability and consumption there appear to be three likely explanations. First, assuming the direction of causality is from availability to consumption, availability may simply be a facilitating factor: if it is there, people may consume it; if it is not there, they cannot consume it. Wansink and Park⁴⁸ examined the association between container size, taste and popcorn consumption and found that there was 53% greater consumption from a large container than a small container. There was no significant effect for taste and no taste by container interaction. Thus, the container size functioned as a facilitator for consumption. The same study group also reported that participants used more cooking oil when it was provided in a large container than a small container, but that this relationship was mediated by cost⁴⁹. Thus, use increased with container size only if the user perceived a cost benefit (e.g. it is ok to use more because it has reduced cost). Applying this finding to F&V suggests that selling F&V in larger, cost-saving containers may result in increased consumption.

Second, external cues such as the sight of freely available F&V may trigger increased consumption. Consumption of chocolate was influenced by availability and convenience, suggesting that the external cue of seeing the food increased consumption⁵⁰. Extension of this finding to F&V suggests that the external cues of viewing conveniently available F&V may at least partially explain the association between availability and consumption. Moreover, storing F&V in prominent locations, in either the home or place of work, may result in increased consumption.

Third, an alternative (and yet complementary) theory is that the association between availability and consumption is a function of increased exposure. This is consistent with the desensitisation and exposure therapies used in clinical psychology⁵¹. Although there is some debate as to the mechanisms by which exposure/desensitisation therapy works, repeated exposure to a phobia and anxiety-causing events has resulted in desensitisation to the event. Appetite for pizza was affected by prior exposure to pizza⁵², suggesting that pizza exposure influenced pizza appetite. Thus, if individuals are more regularly exposed to F&V via increased availability they may be more likely to develop an appetite and taste preference for these foods, which would result in higher intakes. This possibility is supported by research which has shown that increased exposure to a perceived unappetising vegetable resulted in an increase in the preference for that vegetable and increased consumption among 2–6-year-old children⁵³. Similar results have also been reported for baby food among 4- to 7-month-old infants⁵⁴. It is important to note, however, that repeated monotonous exposure was associated with lower consumption of a meat sauce than repeated exposure that included variety⁵⁵. Thus, while frequent exposure in the form of F&V vegetable availability may be important for intake, a strategy that promotes increasing the availability of a wide variety F&V may be more likely to yield sustained increases in consumption.

In light of this evidence, the social ecological framework may prove useful in furthering the understanding of mechanisms by which availability influences consumption and incorporating increased availability into the design of an intervention. The social ecological framework suggests that a person's behaviour is impacted by the environment in which the behaviour occurs, factors unique to the individual, interpersonal factors whereby the individual interacts with his or her peers, and the interactions between these three broad categories^{56,57}. In terms of F&V, increased availability is likely to interact with personal factors, such as taste and preferences, and interpersonal factors, such as other family members' or peers' consumption and beliefs, to result in increased consumption. Thus, addressing these associations may be an effective strategy to increase consumption. A recent intervention included increased availability of F&V at

school lunch (environment), taste sessions to increase preferences (personal factors) and events (interpersonal factors) such as challenge weeks to promote F&V consumption in the school. The study resulted in a 0.14 serving per day ($P = 0.03$) difference in the F&V consumption of intervention and control schools. While this difference was small, the study provided insights into how it is possible to effectively incorporate increased availability into a social ecological framework intervention, which warrants further examination.

Future research directions

While highlighting associations between F&V availability and consumption this review raises a number of issues that require further consideration. A key task is to gain a greater understanding of the mechanisms by which availability impacts consumption. While we have proposed some mechanisms, they are untested in relation to F&V. Empirical testing of these associations is necessary to develop more effective strategies to transform increased availability into increased consumption.

The biggest gap in this literature is the assessment of policy-level interventions. Norwegian research has shown that elementary students attending a school that provided a free piece of fruit per day consumed an extra 0.7 serving of fruit compared with students in a paying school fruit programme and 0.9 of a serving more than participants without a school fruit programme⁵⁸. US Senator Tom Harkin instituted the US Department of Agriculture's Fruit and Vegetable Pilot Program (FVPP) to distribute free F&V to schools in a number of states⁵⁹. The FVPP evaluation was positive, but included mostly qualitative testimonial data. It is not clear if the FVPP led to increased F&V intake among children or displaced F&V that would have otherwise been eaten at home. However, there is a shortage of studies that have examined policy-level interventions to increase the availability of F&V within the wider community. It is also not clear whether governmental sponsoring of reduced-price F&V will increase home availability and consumption of these foods. Moreover, while it is possible that some of the costs could be offset by increased demand, the economics of such approaches are not clear. At a more local level, more research is needed to understand how to increase availability in work locations, what has to be done to increase availability in work canteens, how work refreshment areas can most effectively promote F&V, what the barriers to promotion are and how they can be overcome.

Conclusions

This review has highlighted that the availability of F&V is associated with intake, that the relationship is sustained over time, and that changes in availability are likely to mediate changes in consumption. The review has also

placed availability in the context of home food shopping practices to demonstrate the broader impacts on home availability. Thus, although the manipulation of availability is likely a key method for obtaining increases in consumption, a greater understanding of the mechanisms involved in the association and the effect of policy-level interventions is needed to appreciate the feasibility of public health interventions that focus on increasing F&V availability.

Acknowledgements

Sources of funding: This paper is a publication of the United States Department of Agriculture/Agricultural Research Service (USDA/ARS) Children's Nutrition Research Center, Department of Pediatrics, Baylor College of Medicine, Houston, Texas, and has been funded in part with federal funds from the USDA/ARS under Cooperative Agreement No. 58-6250-6001. The contents of this publication do not necessarily reflect the views or policies of the USDA, nor does mention of trade names, commercial products or organisations imply endorsement from the US government.

Conflict of interest declaration: None declared.

Authorship responsibilities: All authors participated in the conception of the paper, the search of journals and personal records, abstracting of papers, and drafting and editing of the manuscript.

References

- Riboli E, Norat T. Epidemiologic evidence of the protective effect of fruit and vegetables on cancer risk. *American Journal of Clinical Nutrition* 2003; **78**(Suppl. 3): 559S–69S.
- Joshiyura KJ, Hu FB, Manson JE, Stampfer MJ, Rimm EB, Speizer FE, *et al.* The effect of fruit and vegetable intake on risk for coronary heart disease. *Annals of Internal Medicine* 2001; **134**(12): 1106–14.
- Brady LM, Lindquist CH, Herd SL, Goran MI. Comparison of children's dietary intake patterns with US dietary guidelines. *British Journal of Nutrition* 2000; **84**(3): 361–7.
- Stables GJ, Subar AF, Patterson BH, Dodd K, Heimendinger J, Van Duyn MA, *et al.* Changes in vegetable and fruit consumption and awareness among US adults: results of the 1991 and 1997 5 A Day for Better Health Program surveys. *Journal of the American Dietetic Association* 2002; **102**(6): 809–17.
- Wardle J, Jarvis MJ, Steggle N, Sutton S, Williamson S, Farrimond H, *et al.* Socioeconomic disparities in cancer-risk behaviors in adolescence: baseline results from the Health and Behaviour in Teenagers Study (HABITS). *Preventive Medicine* 2003; **36**(6): 721–30.
- Hoare J, Henderson L, Bates CJ, Prentice A, Birch M, Swan G, *et al.* *The National Diet and Nutrition Survey: Adults aged 19 to 64 years – Summary Report*. London: Office for National Statistics, 2004.
- Baranowski T, Anderson C, Carmack C. Mediating variable framework in physical activity interventions. How are we doing? How might we do better? *American Journal of Preventive Medicine* 1998; **15**(4): 266–97.
- Baranowski T, Lin LS, Wetter D, Resnicow K, Hearn MD. Theory as mediating variables: why aren't community interventions working as desired? *Annals of Epidemiology* 1997; **7**(Suppl.): S89–S95.
- Blanchette L, Brug J. Determinants of fruit and vegetable consumption among 6–12-year-old children and effective interventions to increase consumption. *Journal of Human Nutrition and Dietetics* 2005; **18**(6): 431–43.
- Steptoe A, Perkins-Porras L, McKay C, Rink E, Hilton S, Cappuccio FP. Psychological factors associated with fruit and vegetable intake and with biomarkers in adults from a low-income neighbourhood. *Health Psychology* 2003; **22**(2): 148–55.
- Bere E, Klepp KI. Correlates of fruit and vegetable intake among Norwegian schoolchildren: parental and self-reports. *Public Health Nutrition* 2004; **7**(8): 991–8.
- Neumark-Sztainer D, Wall M, Perry C, Story M. Correlates of fruit and vegetable intake among adolescents. Findings from Project EAT. *Preventive Medicine* 2003; **37**(3): 198–208.
- Campbell CC, Desjardins E. A model and research approach for studying the management of limited food resources by low income families. *Journal of Nutrition Education* 1989; **21**: 162–71.
- Bryant M, Stevens J. Measurement of food availability in the home. *Nutrition Reviews* 2006; **64**(2): 67–76.
- Cullen KW, Baranowski T, Owens E, Marsh T, Rittenberry L, de Moor C. Availability, accessibility, and preferences for fruit, 100% fruit juice, and vegetables influence children's dietary behavior. *Health Education & Behavior* 2003; **30**(5): 615–26.
- Klepp KI, Jones-Webb R, Wagenaar AC, Short B, Murray DM, Forster JL. Measurement of alcohol and tobacco availability to underage students. *Addictive Behaviors* 1996; **21**(5): 585–95.
- Baranowski T, Domel S, Gould R, Baranowski J, Leonard S, Treiber F, *et al.* Increasing fruit and vegetable consumption among 4th and 5th grade students: results from focus groups using reciprocal determinism. *Journal of Nutrition Education* 1993; **25**: 114–20.
- Kirby SD, Baranowski T, Reynolds KD, Taylor G, Binkley D. Children's fruit and vegetable intake: socioeconomic, adult-child, regional and urban-rural differences. *Journal of Nutrition Education* 1995; **27**: 261–71.
- Cullen KW, Baranowski T, Baranowski J, Warnecke C, de Moor C, Nwachokor A, *et al.* '5 A Day' achievement badge for urban boy scouts: formative evaluation results. *Journal of Cancer Education* 1998; **13**(3): 162–8.
- Neumark-Sztainer D, Story M, Perry C, Casey MA. Factors influencing food choices of adolescents: findings from focus-group discussions with adolescents. *Journal of the American Dietetic Association* 1999; **99**(8): 929–37.
- Cullen KW, Baranowski T, Rittenberry L, Olvera N. Social-environmental influences on children's diets: results from focus groups with African-, Euro- and Mexican-American children and their parents. *Health Education Research* 2000; **15**(5): 581–90.
- Vastine A, Gittelsohn J, Ethelbah B, Anliker J, Caballero B. Formative research and stakeholder participation in intervention development. *American Journal of Health Behavior* 2005; **29**(1): 57–69.
- Molaison EF, Connel CL, Stuff JE, Yadrack MK, Bogle M. Influences on fruit and vegetable consumption by low-income black American adolescents. *Journal of Nutrition Education and Behavior* 2005; **37**(5): 246–51.
- Wind M, Bobelijn K, De Bourdeaudhuij I, Klepp K. A qualitative exploration of determinants of fruit and vegetable intake among 10- and 11-year-old children in the low countries. *Annals of Nutrition & Metabolism* 2005; **49**(4): 228–35.
- Hearn MD, Baranowski T, Baranowski J, Doyle C, Smith M, Lin LS, *et al.* Environmental influences on dietary behaviour

- among children: availability and accessibility of fruits and vegetables enable consumption. *Journal of Health Education* 1998; **29**(1): 26–32.
- 26 Quan T, Saloman J, Nitzke S, Reicks M. Behaviours of low-income mothers related to fruit and vegetable consumption. *Journal of the American Dietetic Association* 2000; **100**(5): 567–9.
- 27 Kratt P, Reynolds K, Shewchuk R. The role of availability as a moderator of family fruit and vegetable consumption. *Health Education & Behavior* 2000; **27**(4): 471–82.
- 28 Young EM, Fors SW, Hayes DM. Associations between perceived parent behaviours and middle school student fruit and vegetable consumption. *Journal of Nutrition Education and Behavior* 2004; **36**(1): 2–12.
- 29 Hanson NI, Neumark-Sztainer D, Eisenberg ME, Story M, Wall M. Associations between parental report of the home food environment and adolescent intakes of fruits, vegetables and dairy foods. *Public Health Nutrition* 2005; **8**(1): 77–85.
- 30 Baranowski T, Watson K, Missaghian M, Broadfoot A, Baranowski J, Cullen KW, *et al.* Parent outcome expectancies for purchasing fruit and vegetables: a validation. *Public Health Nutrition* 2007; **10**(3).
- 31 Baranowski T, Missaghian M, Watson K, Broadfoot A, Cullen K, Nicklas T, *et al.* Home fruit, juice and vegetable pantry management and availability scales: a validation. *Appetite* 2006; submitted.
- 32 Befort C, Kaur H, Nollen N, Sullivan D, Nazir N, Choi WS, *et al.* Fruit, vegetable, and fat intake among non-Hispanic Black and non-Hispanic white adolescents: associations with home availability and food consumption settings. *Journal of the American Dietetic Association* 2006; **106**(3): 367–73.
- 33 Bere E, Klepp KI. Changes in accessibility and preferences predict children's future fruit and vegetable intake. *International Journal of Behavioral Nutrition and Physical Activity* 2005; **2**: 15.
- 34 Patterson RE, Kristal AR, Shannon J, Hunt JR, White E. Using a brief household food inventory as an environmental indicator of individual dietary practices. *American Journal of Public Health* 1996; **87**(2): 272–5.
- 35 Satia JA, Patterson RE, Kristal AR, Hislop TG, Pineda M. A household food inventory for North American Chinese. *Public Health Nutrition* 2001; **4**(2): 241–7.
- 36 Raynor HA, Polley BA, Wing RR, Jeffery RW. Is dietary fat intake related to liking or household availability of high- and low-fat foods? *Obesity Research* 2004; **12**(5): 816–23.
- 37 McKie L, Clark GM, Maclellan M, Skerratt S. The promotion of healthy eating: food availability and choice in Scottish island communities. *Health Education Research* 1998; **13**(3): 371–82.
- 38 Naska A, Vasdekis VG, Trichopoulou A, Friel S, Leonhauser IU, Moreiras O, *et al.* Fruit and vegetable availability among ten European countries: how does it compare with the 'five-a-day' recommendation? DAFNE I and II projects of the European Commission. *British Journal of Nutrition* 2000; **84**(4): 549–56.
- 39 Edmonds J, Baranowski T, Baranowski J, Cullen KW, Myres D. Ecological and socioeconomic correlates of fruit, juice, and vegetable consumption among African-American boys. *Preventive Medicine* 2001; **32**(6): 476–81.
- 40 Cummins S, Macintyre S. A systematic study of an urban foodscape: the price and availability of food in Greater Glasgow. *Urban Studies* 2002; **11**: 2115–30.
- 41 Rose D, Richards R. Food store access and household fruit and vegetable use among participants in the US Food Stamp Program. *Public Health Nutrition* 2004; **7**(8): 1081–8.
- 42 Baranowski T, Davis M, Resnicow K, Baranowski J, Doyle C, Lin LS, *et al.* Gimme 5 fruit, juice, and vegetables for fun and health: outcome evaluation. *Health Education & Behavior* 2000; **27**(1): 96–111.
- 43 Davis M, Baranowski T, Resnicow K, Baranowski J, Doyle C, Smith M, *et al.* Gimme 5 fruit and vegetables for fun and health: process evaluation. *Health Education & Behavior* 2000; **27**(2): 167–76.
- 44 Baranowski T, Baranowski J, Cullen KW, deMoor C, Rittenberry L, Hebert D, *et al.* 5 a day Achievement Badge for African-American Boy Scouts: pilot outcome results. *Preventive Medicine* 2002; **34**(3): 353–63.
- 45 Perry CL, Bishop D, Taylor GL, Davis M, Story M, Bishop SC, *et al.* A randomized school trial of environmental strategies to encourage fruit and vegetable consumption among children. *Health Education & Behavior* 2004; **31**(1): 65–76.
- 46 Bere E, Veierod MB, Bjelland M, Klepp KI. Outcome and process evaluation of a Norwegian school-randomized fruit and vegetable intervention: Fruits and Vegetables Make the Marks (FVMM). *Health Education Research* 2006; **21**(2): 258–67.
- 47 Yoo S, Baranowski T, Missaghian M, Baranowski J, Cullen K, Fisher J, *et al.* Food-purchasing patterns for home: a grocery store-intercept survey. *Public Health Nutrition* 2006; **9**(3): 384–93.
- 48 Wansink B, Park SB. At the movies: how external cues and perceived taste impact consumption volume. *Food Quality and Preference* 2001; **12**: 69–74.
- 49 Wansink B. Can package size accelerate usage volume? *Journal of Marketing* 1996; **60**: 1–14.
- 50 Painter JE, Wansink B, Hieggelke JB. How visibility and convenience influence candy consumption. *Appetite* 2002; **38**(3): 237–8.
- 51 Tryon WW. Possible mechanisms for why desensitization and exposure therapy work. *Clinical Psychology Review* 2005; **25**(1): 67–95.
- 52 Marcelino AS, Adam AS, Couronne T, Koster EP, Sieffermann JM. Internal and external determinants of eating initiation in humans. *Appetite* 2001; **36**(1): 9–14.
- 53 Wardle J, Cooke IJ, Gibson EL, Sapochnik M, Sheiham A, Lawson M. Increasing children's acceptance of vegetables; a randomized trial of parent-led exposure. *Appetite* 2003; **40**(2): 155–62.
- 54 Birch LL, Gunder L, Grimm-Thomas K, Laing DG. Infants' consumption of a new food enhances acceptance of similar foods. *Appetite* 1998; **30**(3): 283–95.
- 55 Zandstra EH, de Graaf C, van Trijp HC. Effects of variety and repeated in-home consumption on product acceptance. *Appetite* 2000; **35**(2): 113–9.
- 56 McLeroy KR, Bibeau D, Steckler A, Glanz K. An ecological perspective on health promotion programs. *Health Education Quarterly* 1988; **15**(4): 351–77.
- 57 Stokols D. Establishing and maintaining healthy environments. *American Psychologist* 1992; **47**(1): 6–22.
- 58 Bere E, Veierod MB, Klepp KI. The Norwegian School Fruit Programme: evaluating paid vs. no-cost subscriptions. *Preventive Medicine* 2005; **41**(2): 463–70.
- 59 Buzby JC, Guthrie JF, Kantor LS. *Evaluation of the USDA Fruit and Vegetable Pilot Program: Report to Congress*. Washington DC: Nutrition Research Program, Economic Research Service, US Department of Agriculture, 2003.