Title: **INCREASING VEGETABLE INTAKES: UPDATED SYSTEMATIC REVIEW OF PUBLISHED INTERVENTIONS**

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ABSTRACT

Vegetable consumption is important for a variety of health reasons, yet intakes are typically lower than recommended. Interventions to improve fruit and vegetable consumption are available, but these interventions are typically more successful for fruit consumption, while vegetable intakes remain low. This chapter details the interventions currently available that focus specifically on improving vegetable intakes. A systematic review of the published literature was conducted in 2015, and this has been updated for this chapter. Databases - PubMed, PsychInfo and Medline were searched over all years of records until January 2017 using pre-specified terms. Our searches identified 119 studies, detailing 206 interventions. Interventions aimed to use or change hedonic factors, such as taste, liking and familiarity (n=103), use or change environmental factors (n=54), use or change cognitive factors (n=28), or a combination of strategies (n=21). Increased vegetable acceptance, selection and/or consumption were reported to some degree in 186 (90%) interventions. Greatest success appears to be achieved in interventions that improve education, change the environment or use multiple approaches, but long-term success and cost-effectiveness are rarely considered. A focus on long-term benefits and sustained behaviour change is required.

Keywords: vegetables, interventions, systematic review, published literature

INTRODUCTION

The benefits of a high vegetable consumption for health are well reported (e.g.1-5), but vegetable intakes across Europe and the US remain lower than recommendations (e.g.6,7). These low intakes testify to a need for interventions and strategies specifically to increase vegetable intakes. We recently undertook and published a systematic review of the published literature investigating interventions to increase vegetable-specific intakes (8). This work updates this systematic review to identify from the published literature all studies to date reporting an intervention to increase vegetable intakes, where vegetables were considered as a separate and distinct food group.

SYSTEMATIC REVIEW

Only interventions that target vegetables as a separate food group are considered. Many interventions target fruit and vegetable intakes [eg. 9,10) or target vegetables and another food group, e.g. wholegrains (e.g.11,12), but many interventions that target several food groups demonstrate poor success for improving vegetable intakes compared to the improved success often found for improving fruit intakes or the intakes of other foods (13-15). Interventions are arguably more likely to achieve success if based on the specific barriers to consumption or determinants of low consumption, and the barriers to consumption of vegetables are different to those of fruit and other foods. Fruit particularly, is typically sweet in taste and soft in texture, while vegetables can taste bitter and are generally harder in texture (16-19). Fruit is also easily consumed raw, and is more frequently consumed and considered acceptable as a snack, a drink or as dessert (16-19), while vegetables are more often in need of preparation and cooking before consumption, and are typically consumed and considered more acceptable as part of a meal (16-20). The bitter taste and increased need for preparation and cooking are frequently cited barriers to the consumption of vegetables, and more so than for other foods. Studies investigating barriers specifically to fruit consumption and vegetable consumption report these differences. In an Australian sample, Glasson et al, 2011 (21), report fruit consumption to be largely prevented by cost, food preferences, quality, availability and wastage concerns, while vegetable consumption was more frequently prevented by food preferences, lack of time, cost and taste. Chapman et al, 2016 (22) report fruit consumption to be largely prevented by habit, preferences for other foods over fruit, concerns about perishability, cost and laziness, while vegetable consumption was more often prevented by beliefs that people already ate enough vegetables, preferences for other foods, habit, cost and concerns about perishability. Interventions were also only included in our review if they aimed to increase a vegetable-related behaviour – vegetable selection, vegetable purchasing or

vegetable intake. Many studies consider important correlates of behaviour as outcomes, such as liking, attitudes and nutritional knowledge (e.g.23-25), but it is only behaviour that will impact on health. While we appreciate the importance of these non-behavioural correlates of behaviour, this review only considers studies that involve behaviour as an outcome.

For the initial review (8), three databases: Pubmed, PsychInfo, and Medline were searched over all years of records until 28th April, 2015, for all studies published with the terms 'vegetable' or 'vegetables' in the 'title'. Searches were conducted and then all titles and abstracts were screened for relevance independently by two review authors. For this update, records in the three databases were searched over 2015 and 2016 by one review author and checked by another. Studies were included only if they involved a relevant intervention. Studies were not included if they did not include an intervention, if the intervention targeted fruit and vegetable intakes (e.g.9,10), if the intervention targeted vegetables and other foods, e.g. vegetables and wholegrains (e.g.11,12); if the intervention involved changing consumption as opposed to increasing consumption (e.g.26), or if they did not include a measure of behavior (e.g.23-25). Studies measuring amount tasted or willingness to try a vegetable were included where tasting was voluntarily, where amount tasted was voluntary and where tasting/amount was measured, but studies where tasting was compulsory and/or pre-specified, e.g. to make hedonic judgements, were not included (e.g.27,28). Studies were included regardless of the use or not of a comparison for the intervention, or the type of comparison used. Relevant articles were also searched for other suitable studies. A number of reviews were also found in the update searches, and the reference lists for review articles were also searched for relevant articles. In searching review articles, we considered articles regardless of their inclusion of the terms 'vegetable' or 'vegetables' in the title. This resulted in the inclusion of several studies published earlier than 2015 that were previously unidentified but were of relevance.

INTERVENTIONS

Update searches were conducted on 9th January, 2017. Search updates resulted in the inclusion of 2,846 new database entries, which resulted in the inclusion of 41 new studies in the review. Including those identified in the original review, a total of 119 studies are currently published that report the impacts of 206 interventions aiming to increase vegetable intakes. These interventions are grouped for reporting based on the barriers or determinants they seek to address.

Interventions aiming to change or use hedonic factors

Taste, familiarity and hedonic factors such as preferences and likings, are key determinants of the majority of food consumption (29,30), and both the poor taste, low liking and low familiarity with vegetables are frequently reported barriers to the consumption of vegetables across the lifespan (21,31-35). Vegetable consumption is higher, for example, in families where vegetables are disguised or sauces are used to mask undesirable tastes (36-38), where vegetables are more often incorporated into composite foods as opposed to consumed alone to dilute negative tastes (36), and where meals are home cooked to accommodate individual preferences (37). Two interventions were found where intakes of familiar vegetables / vegetable dishes were compared to those of novel dishes (39,40), and ten interventions were found where the taste of a vegetable or vegetable dish was deliberately manipulated on a single occasion through the addition of salt (41,42), fat (41), condiments (43) or a dip (44). These interventions are described in Table 1. With the exception of the manipulation of additional fat, all studies demonstrated increased intakes for more familiar and more tasty vegetables or vegetable dishes. Increasing salt, sugar and fat intakes via the use of table salt and commercially available dips and sauces may be unwise, but herbs, spices and low-sugar or low-fat dips and sauces are alternatives that may add taste and not detrimentally impact on dietary profiles.

Table 1 about here

Eighty-two interventions were also found that focus on increasing familiarity and liking with repeated experience. These interventions are based on the premise that familiarity and liking increase with increasing experience and increasing positive experience respectively, thus aim to increase familiarity with, liking for and intakes of vegetables through repeated experience and repeated positive experience. Thirty-three interventions were found using repeated exposure, and forty-nine interventions were found that involved repeated positive experience of vegetables via pairing with liked flavours (n=12), pairing with beneficial nutrients (n=6), pairing with flavours and nutrients (n=9), pairing with foods usually consumed at the same time (n=1), pairing with external reinforcement or rewards (n=11). Nine interventions also used positive role models as a form of vicarious reinforcement, and one intervention used a combination of models and rewards. Studies using these interventions are described in Table 2. Many of these interventions demonstrate success by improving liking and/or consumption: 26 of 32 (one protocol only) (81%) interventions using repeated exposure; 10 of 12 (83%) using pairing with liked flavours; three of six (50%) using pairing with nutrients; 7 of 9 (78%) using pairing with

flavours and nutrients; the one using pairing with usual foods; 9 of 11 (82%) using pairing with reinforcement, 7 of 9 (78%) using modelling, and the one using modelling and rewards. Effects, however are far from robust or consistent (ie. effects are often found in one measure, but not in others), effects are often small, and tend to be limited to the specific vegetable used during the exposure manipulation, and tend to remain only for a very limited period. Conditions within studies, furthermore, are often confounded, making mechanisms difficult to elucidate. In many studies that purport to investigate exposure, for example, the exposure is given in combination with other food components (e.g.54) which may be positive, or the exposure is combined with the positive experience of rewards in the form of praise or other positive interactions (e.g.74) or modelling (e.g.33). In many studies that purport to measure positive experiences, exposure is not controlled for (e.g.63,88). Many of these interventions furthermore also involve children's parents, and so may have benefits not just by allowing tasting and experience for the child, but also by improving parental perceptions of vegetables, improving attitudes towards vegetables in the home, and improving parental education and knowledge (e.g.33). Interestingly, some of the interventions included in Table 2 report parental opinions of the intervention (33,54), but as far as we can tell, none specifically tested parental knowledge or education as a result of the intervention for their children.

Table 2 about here

While largely successful, particularly over considerable exposures, exposure, however, is a relatively time-consuming practice that results in small changes, and typically only for the vegetable to which children have been exposed. Nine interventions have extended the use of exposure to consider exposure to vegetables via picture books and stories. Studies that use these interventions are detailed in Table 3. These procedures appear beneficial, although few studies have currently tested these ideas, and effects again appear small or unreliable, and typically only apply to the vegetable to which the child has been exposed. Little evidence suggests that effects generalise to other vegetables, so neither taste nor visual exposure appears to encourage consumption of a variety of vegetables. Repeated exposure to many vegetables may result in increased consumption of many vegetables, and some studies are beginning to demonstrate these effects (e.g.95,96), but generalization of exposure to non-exposed vegetables has not yet been demonstrated reliably either through the use of taste or visual stimuli. The potential for exposure to multiple as opposed to single vegetables, however, may be greater using visual as opposed to taste stimuli.

Table 3 about here

The majority of the interventions based on taste and liking have been conducted in children. Early intervention will maximize health benefits of an increased vegetable consumption (15) and eating habits in childhood are likely to extend into adulthood (33,34). Children are also particularly likely to reject bitter tastes. Without the experience of a wide range of tastes as will be gained throughout the lifespan, children are known to rely more on primitive taste preferences. A reluctance to eat, or the avoidance of, novel foods, referred to as food neophobia (97)) also typically peaks at around 2-3 years of age, and can interfere heavily with young children's acceptance of vegetables (97-99). This neophobia typically results in the rejection of bitter tasting foods. Neophobic tendencies can also last well into adulthood, and typically correlate negatively with liking for and frequency of vegetable consumption in adulthood (100,101). The transfer of childhood eating habits and food preferences into adulthood is well known, and adult vegetable intake is often related to childhood experiences (34). Some studies using taste for increasing vegetable consumption have involved older children, and studies employing taste for encouraging the consumption of fruit and high protein foods have demonstrated success in adults and older adults (102-104), but as far as we are aware no studies have used these techniques specifically for increasing vegetable intakes in adults.

Interventions based on changing the environment:

A further key determinant of the majority of food consumption, and important in vegetable consumption also, is food availability or the ready and easy availability of food in the form in which it will be eaten (105-109). For adults, higher vegetable consumption is highly related to increased availability (105,108,109) and reduced cost (21,35,110,111), and low consumption is largely associated with lower socio-economic status (112,113), lower income (13,109), living in a more deprived area or lower income neighbourhood (13) and lower education (112,114). For children, the availability of food depends largely on adults and the home environment, and low vegetable consumption in children is frequently associated again with some socio-demographic factors and with various characteristics of the family environment (106,107,115-117). Relevant factors include low parental education and socio-economic status (106,115-117), low vegetable consumption and modelling by parents and caregivers (37,38,107,118), low availability of vegetables in the home (106,107,119) and a family environment that includes negative perceptions or is unsupportive of vegetable consumption (37,38,107,119,120). The

expression of neophobic behaviour towards vegetables also appears to be mitigated by high parental education and socio-economic status (97,121) and again by a positive and supportive environment (122,123). Low vegetable consumption in adolescents has again been associated with low parental education and socio-economic status (124), low vegetable consumption by the parents (125,126), low availability and a family environment that is unsupportive of vegetable consumption (124,126,127). Higher vegetable consumption was also associated with increased purchasing from supermarkets (128). Given the importance of adult consumption for children, many of the determinants of adult consumption will also impact on child consumption. For children and adults alike, the presentation of vegetables can also be important. Food neophobia has been found to result in the rejection of foods that do not ''look right'' (97), of which vegetables are good examples, and vegetable consumption with sauces and in composite dishes will not only disguise negative tastes, but may also mask undesirable appearances (36-38).

Interventions that focus on changing the environment and increasing consumption through increasing the provision of vegetables, or improving the manner in which provision is implemented are given in Table 4. Fifty-four interventions were found. All of these, with the exception of two interventions increasing provision (142,155), two interventions increasing variety (54,131), and two interventions improving presentation (76,141), resulted in increased selection and/or consumption of vegetables, through the increased provision of vegetables (n=23), through the increased provision of a variety of vegetables (n=9), through improved presentation (n=9), through changing the texture (n=1), through changing the location of vegetables (n=1), through changing the order in which vegetables and other foods are served (n=2), and through changing the serving order, while also increasing availability (n=3). Increased consumption as a result of increased provision is unsurprising, but concerns have been raised regarding increased energy intakes as a result of increased consumption, and increased potential for food wastage (e.g.147,155,156). An absence of effects on overall energy intakes is reported in some studies (135), and concerns are mitigated if vegetables are substituted for other foods in the meal as opposed to simply added (135). Increased food waste has been reported (e.g.147), and suggestions to reduce potential food wastage include the use of family style serving dishes for individual meals (133,136) or allowing differential selection, but again the cost-effectiveness of interventions that can increase waste will be questioned. Strategies that improve the presentation of vegetables may offer a valuable alternative. These interventions typically change the salience or likely appeal of vegetables (e.g.76,142,143), and have again demonstrated success, but relatively few studies are currently

available. Exact mechanisms however are unclear – attractive labels may rely partly on modelling, effects due to serving order may rely partly on hunger and exposure, but the relative ease and low cost of these interventions add to their value.

Table 4 about here

Interventions based on changing or using cognitive factors

While food consumption in general is largely determined by hedonic factors and availability, cognitive factors are a major determinant of healthy food consumption (157,158). Vegetable consumption specifically has been associated in adults with a higher appreciation of health and the value of a healthy diet (34), and with greater nutritional knowledge, culinary knowledge and culinary confidence (110,159,160). Vegetable consumption has also previously been associated with several related food habits and eating practices (108,161), including usual consumption of meals as opposed to snacks (34,162), increased time and willingness to prepare and cook home-made meals (21,34,35,110), and a low consumption of fast food (34). Many of these determinants require not just an interest in health, but a willingness to commit time and resources to improving health. Vegetable consumption in adolescents has also been associated with an awareness and interest in health (127,128), self-efficacy regarding healthy eating (126,128), a willingness and ability to ask for vegetables from parents (127), and reduced purchasing by parents from fast food outlets (128).

Twenty-eight interventions were found that used information, education or other cognitive techniques to increase vegetable consumption. These interventions are described in Table 5. The majority of these interventions are aimed at older audiences (those where cognitive factors have a greater impact on vegetable consumption and non-consumption), and used a range of techniques from providing information and education on nutrition (n=8), providing information or education on nutrition-related skills (n=2), providing education plus a demonstration or gardening experience (n=3), providing tailored information (n=2), providing information on social norms (n=6), invoking choice (n=6) and invoking a memory (n=1). Our searches also identified one paper that demonstrates the importance of cognitions for vegetable consumption, but the effects demonstrated are yet to be translated into an intervention (178). This study demonstrated a reduced vegetable consumption following dissociation from unhealthy brand labels, as a result of the cognitive effort required for dissociating from unhealthy brand labels and for vegetable consumption, and suggests interventions using branding for increasing vegetable

consumption may be possible, but these are yet to be developed. This study thus, while identified in our searches, is not included in our tables. With the exception of one intervention that aimed to educate (33), and two interventions that utilised choice (162), all of the studies using cognitive strategies reported success to some degree, but multiple measures of impact are often taken, and success is not necessarily reported for all measures. The cost-effectiveness of these types of interventions can also be questioned. Educational interventions can be costly, particularly those involving classes or courses to be delivered by a professional, but the long term benefit of these interventions can also be difficult to assess. Knowledge accumulates over time and experience, and it can be difficult for individuals to pinpoint the exact source / sources of beneficial education.

Table 5 about here

Multi-component interventions:

Finally, the majority of individuals fail to consume adequate quantities of vegetables for multiple reasons or differing reasons at multiple time-points, thus interventions are available that aim to tackle a number of determinants of poor consumption at one time. These multi-component interventions involve a combination of strategies. Twenty-one of these interventions were found as described in Table 6. Again all the published reports evaluating these interventions report success, but again multiple measures are often taken, which demonstrate varying degrees of benefit. These types of intervention can also be time consuming and costly to implement. Success is furthermore not often easily attributable to the combination of many strategies as opposed to the use of any single one.

Table 6 about here

DISCUSSION

A variety of interventions for increasing vegetable intakes are currently available, and many of these report success to some degree. Greatest success is reported currently from the interventions focusing on changing the environment, improving education and from the multi-component interventions using a combination of approaches. The majority of interventions published in the last two years utilise an increase in the provision of vegetables or the improved presentation of vegetables (see Table 4), or multiple strategies (see Table 6). The increase in publication of these types of intervention most likely

reflects a current interest in behavioural interventions based on automatic processing (nudging), and a quest by researchers to find interventions that work by combining a number of strategies. Evaluation periods, however, remain typically short, effect-sizes can be small, and the studies that use longer follow-up periods often report reductions in effect size as follow-up periods are extended. Cost-effectiveness is also rarely considered. Cost-effectiveness becomes an increasing concern in long lasting and multi-component interventions, but it can be difficult to assess the long term benefit of some interventions. Education, knowledge and experience, for example, will accumulate over time, and it can be difficult to attribute increased intakes to any particular gain in knowledge or intervention. Further work is clearly still required. A greater number and variety of intervention evaluations would increase the evidence base, and more reliably inform future policies. Longer term follow-ups for interventions are important, and consideration of more sustainable behaviours or the more sustainable elements of behaviour, such as habit formation, would be of value.

The majority of studies so far, also target children or other easy-to-reach groups. Vegetable consumption is known to be particularly low in individuals of low education and of low socio-economic status (195), but few of the interventions published to date focus on or even include individuals with these demographic characteristics. Certain age groups are also noticeably absent from the list of current studies. Adolescents and older adults would benefit also from improved vegetable intakes for improved health. Many of the determinants of vegetable intakes also apply to many different demographic groups, thus interventions in one population group may benefit other groups also. Taste strategies to increase liking, for example, have been found to increase fruit consumption in older adults as well as children (102) and are currently being tested in adults for vegetable consumption (91). We recommend careful consideration of barriers however, and caution against a 'one size fits all' approach. While interventions may be successful across individuals and population groups, testing is clearly required. Comparisons of interventions could also be helpful. Multi-component interventions are rarely unpicked to investigate the successful component, yet comparing interventions, or the identification of more effective intervention components could contribute considerably to understanding, lasting impact and improved cost-effectiveness. Several types of broader population-based interventions have also not yet been considered specifically for vegetable consumption. Strategies such as pricing and marketing, improved product provision, government subsidies, and population-wide awareness and education campaigns (see 196-198) specifically for vegetables do not yet exist, or have not yet been evaluated as far as we are aware.

CONCLUSION

In conclusion, a variety of interventions for increasing vegetable intakes are currently available that have been tested and evaluated. Greatest success is currently achieved for interventions that focus on changing the environment, improving education and that use a combination of strategies. Considerable further work however is required to identify impacts over the long-term and establish cost-effectiveness and sustainability.

CONTRIBUTIONS OF AUTHORS

KMA led and undertook the systematic review and wrote the manuscript, AH and HH also undertook aspects of the systematic review and update. All authors reviewed and offered critical comments on the manuscript.

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CONFLICTS OF INTEREST

L Depezay and E Castagna are employees of Bonduelle, Villeneuve D'Ascq, France, a vegetable processing company. There are no other conflicts of interest.

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