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Diet adherence dynamics and physiological responses to a tomato product whole-food intervention in African–American men

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Abstract

Tomatoes may have beneficial effects on prostate health. Efficacy trials would require long-term adherence to high levels of tomato product (TP) consumption. Therefore, factors that affect adherence in men most at risk and whether increased consumption of TP negatively affects diet and health are important concerns. Cancer-free African–American (AA) men (n 36) with mean serum prostate-specific antigen of 7·4 SD 5·6) ng/ml were randomised to consume one serving of TP/d or a control diet for 3 months. Mean intervention group lycopene intake rose to 464 %, with negligible control group increase. Plasma lycopene levels rose by 53 and 40 % in the intervention group in months 1 and 3, respectively ($P<0·0001$), with no control group change. The intervention group's barriers to adherence score was inversely associated with both dietary (r −0·49, $P=0·02$) and plasma lycopene concentration (r −0·37, $P=0·02$). Their TP disadvantage score negatively correlated with the 3-month plasma lycopene concentrations (r −0·37, $P=0·008$) and their weekly incentives and impediments were remarkably stable, 'concern for prostate health' being the most consistent over time. 'Liking tomatoes' and 'study participation' decreased in citation frequency at weeks 6 and 9, respectively. No major shifts occurred in dietary cholesterol or saturated fat, with no adverse effects on gastrointestinal complaints, serum total cholesterol, body weight or blood pressure. Lower socio-economic status AA men at higher prostate cancer risk can successfully achieve a whole food intervention goal with a corresponding rise in plasma lycopene concentrations, with no adverse effects on self-selected diet quality or health parameters.

Key words: Prostate cancer: Adherence: Tomato products: Lycopene

Widespread low adherence in diet intervention studies may be due to the complexity of the required change[1,2]. For example, an analysis of ninety-two independent fruit and vegetable intervention studies found that 75 % of studies reported statistically significant increases in fruit and vegetable intake that averaged only 0·6 servings/d, a value far short of the goals in most of these studies[3]. Interventions that seek to change dietary patterns, a worthy goal for chronic disease prevention, make it difficult to unpack and study the dynamics of dietary adherence and non-adherence. Adherence may be better when people are advised to consume a single whole-food class as a beginning strategy and the dynamics of compliance should be simpler to interpret. Such studies have not been published, especially for vulnerable populations.

African–American (AA) men suffer the greatest proportion of health disparities of any studied category[4,5], and adherence to advice among this group has been vastly understudied. Although there are several ongoing trials for behavioural change, either of diet or of lifestyle[6–8], enrolment rates of AA men (< 25 %) often provide insufficient numbers to evaluate adherence issues separately[9–13]. AA men are hesitant to participate in clinical trials or to adopt to medically related prevention approaches because of suspicion instigated from the widespread knowledge of the Tuskegee Institute Syphilis Trials[14], mistrust of the medical community[15,16], lack of access to medical care and concerns about screening and treatment[17]. Knowledge of low socio-economic status AA male recruitment, adherence, drop-out and join-in rates is necessary for robust clinical trial design.

AA men pose a special challenge for prostate health promotion because they have the world's highest incidence of prostate cancer (PC) along with a higher mortality rate[18],

Abbreviations: AA, African–American; AICR, American Institute for Cancer Research; PC, prostate cancer; TP, tomato products.

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British Journal of Nutrition

and would benefit from robust, economically viable prevention strategies. One of the more promising whole-food candidates for PC prevention is tomato products (TP). A Food and Drug Administration systematic review of a submitted health claim for lycopene or tomatoes gave support for a modest preventive effect of tomato consumption for PC, although there was insufficient evidence for lycopene[19]. TP contain bioactive substances other than lycopene that may have cancer-preventive activity[20,21], and studies using animal PC models found TP to be more protective than lycopene alone[22]. Whole-food PC intervention trials, such as those using TP, could only be accomplished by voluntary adherence through self-selection of a variety of TP in the open market. A whole-food intervention necessarily displaces other foods in the diet. TP (pizza, ketchup, spaghetti, chilli and tomato juice) have a reputation for being acidic, high in Na and are often served with cheese and/or meat high in cholesterol and saturated fat. Therefore, increased TP intake may have unintended public health consequences.

The aim of the study was to assess the feasibility of a TP intervention in older AA men with low socio-economic status, and to determine adherence factors and the incentives and impediments of doing so in the midst of their effort. Accompanying shifts in diet patterns that may affect CVD risk factors were also explored.

Methods

Subjects

Participants were AA men aged ≥45 years, recently found to have serum prostate-specific antigen concentrations of >2·5 ng/ml, with negative prostate biopsy for PC. The Urology Clinic at the Jesse Brown Veteran's Administration Medical Center was the site of recruitment. Exclusion criteria were PC diagnosis, other cancers <5 years post-diagnosis, except for melanoma, already consuming five half-cup servings of TP/week.

The study was conducted according to the guidelines laid down in the Declaration of Helsinki, and all procedures involving human subjects/patients were approved by both the Institutional Review Board at University of Illinois at Chicago and the Research and Development Committee at Jesse Brown Veteran's Administration Medical Center. Written informed consent was obtained from all subjects. The study was conducted from June 2007 to August 2008 (ClinicalTrials.gov registration number: NCT01408459).

Study design

The study was a 3-month phase II, parallel-arm control group primary prevention study. The intervention was diet counselling to affect an increase in the consumption of TP in addition to the American Institute for Cancer Research (AICR) eating plan, which was provided to both the intervention and the control groups. Outcome assessments were blinded. Those who were willing and pre-eligible attended an initial screening visit to qualify them for the study, signed the consent, filled out a contact–demographic–environment questionnaire, had height and weight measured and were trained for the 24 h diet recall. Three additional telephone diet recalls were collected during the baseline period.

The intervention

AA men were randomised to either be coached to increase their TP consumption or to a control group receiving no TP coaching. After randomisation, each group attended their own orientation session that included a PowerPoint presentation that described PC, its incidence in AA men, how it developed and its risk factors. The control group session included dietary advice for cancer prevention based on the AICR eating plan. The intervention group session included the same description of PC, but in addition, the intervention group was provided with the scientific rationale for increasing TP in their diet to prevent PC along with the prescription to follow the AICR eating plan and to include at least one serving/d of TP in their diet. Standard serving sizes for various TP were provided. The sessions ranged from one to four participants, with an occasional spouse as recruitment proceeded. The intervention group also received individual weekly telephone coaching and colourful newsletters that contained (a) information about prostate health and its promotion, especially focused on AA male concerns, (b) information on tomatoes, (c) cartoons and jokes about tomatoes or prostate health and (d) TP recipes. The intervention group was sent home with six packs of V8 juice (low Na or regular, according to preference), lasagna noodles and two large cans of tomato sauce. The control group was sent home with four packs of apple or grape juice, and individual servings of canned fruit and boxes of raisins. Both groups were mailed six AICR brochures through the course of the 3-month intervention period. All participants made three clinic visits at baseline, 1 month and 3 months for blood samples, blood pressure, body weight and bioelectric impedance measurements and to fill out adverse symptoms forms.

Assessment of factors affecting adherence

A questionnaire was developed based on social cognitive theory that identified four domains that may modulate behaviour change: personal background (external, medical and knowledge), cognitive (self-efficacy, health belief and perceived susceptibility), social (support and reinforcement) and environmental (opportunities, e.g. barriers and food deserts)[23,24]. Study-specific items were constructed for each domain and incorporated into a questionnaire (described later) along with demographic information that might make an impact on adherence. Two identical questionnaires were constructed with certain items/scales modified to reflect the adherence assignment, TP consumption or AICR diet alone. These were administered after the orientation presentation but before the intervention commenced. In addition, short-term effectors were assessed weekly during the intervention telephone call only.

British Journal of Nutrition

Questionnaire development

Before recruitment, eight AA men, in the same demographic as the target population, evaluated the screening demographic–health–environment questionnaire. It took the pre-validation respondents 10–15 min to complete the questionnaire. Responses from open-ended questions were categorised into fixed-choice scales for the final versions of the questionnaire. Of particular importance for the intervention group questionnaire were scaled questions for: (1) level of concern about PC, (2) level of belief that PC can be prevented, (3) knowledge of tomato–PC connection, (4) level of belief that TP can prevent PC, (5) perceived ability to increase TP consumption, (6) social support and reinforcement, (7) environmental factors such as power over food choice, food purchasing and preparation and (8) intention to increase TP consumption. The control group questionnaire had the same questions that were directed towards increased fruit and vegetable intake and decreased meat and sugar intake. We were unable to perform statistical validation for internal consistency.

Adherence assessment during the intervention

The intervention group was contacted by telephone twice weekly for the first 2 weeks, then weekly for the next 2·5 months. A total of twelve 24 h diet recalls and weekly counts of TP intake were collected during the calls, along with the incentives and barriers to compliance encountered by the participants on the previous day. The telephone interview had three objectives: (a) to obtain detailed diet information for the previous day plus 1 week intake of TP and their type, (b) encountered incentives and impediments to the consumption of TP in the midst of the attempt and (c) coaching to improve and maintain adherence using motivational interviewing. Although men were coached to consume at least one TP/d, the study compliance standard was set at more than five servings/week. A serving was defined (for example) as a half cup of tomato sauce, two tablespoons of ketchup, a half cup of fresh tomatoes, a half cup of canned tomatoes or 6 oz of juice containing 19·5, 5·1, 5·9, 11·6 and 16·4 mg lycopene, respectively. The goal was to double the daily lycopene intake as a marker of TP exposure (we estimated an increase in intakes from <5 mg lycopene/d to a mean of 10 mg/d) and also baseline plasma lycopene concentrations by 50 %.

Control group participants were called bi-weekly to obtain diet recalls (total of six recalls) and feedback on the usefulness of the pamphlets throughout the 3-month period. Fewer telephone calls to the control group were because of concern that a more active assessment might produce greater adoption of TP into their diet.

Assessments of diet composition, gastrointestinal complaints and physiological changes

Diet composition. The multiple-pass method[25,26] was used by the interviewers, with the inclusion of weekdays and weekend days. The latest version of the Nutrition Data System for Research (Nutrition Coordinating Center, University of Minnesota, Minneapolis, MN, USA, 2008) was used to assess mean daily intakes of lycopene, other carotenoids, energy, saturated fat, cholesterol and food-based Na. The 24 h recall technique was chosen because previous experience showed poor compliance with diet record keeping in this population and food checklists lacked sufficient specificity. The mean of four screening recalls was used as baseline and compared with the mean of twelve recalls for the intervention group and six recalls for the control group. Weekly tomato serving frequency was collected only from the intervention group, who were coached to perceive that the cause of success or failure was an important study objective.

Plasma lycopene concentrations. Total plasma lycopene levels were assessed by HPLC-UV/VIS (Waters Corporation) along with lutein, β-cryptoxanthin, α- and β-carotene, α- and γ-tocopherol and retinol[20]. The peaks were detected by a Waters 490 Programmable Multiwave length Detector with four channels, each analyte at its specific maximum absorbance (325 nm for vitamin A compounds, 295 nm for vitamin E compounds, 450 nm for carotenoids other than lycopene and 472 nm for lycopene). The detection limits were 0·5 mM for tocopherols, 3·5 nM for lutein and 9 nM for other carotenoids. The within-assay variability (CV) ranged from 1 % for retinol and lutein to 7·1 % for α-carotene and was 2·7 % for lycopene. The between-assay CV ranged from 1·2 % for retinol to 7·4 % for lycopene[27]. All samples from a single individual were measured within the same assay. We are a National Institute of Standards and Technology (NIST) reference laboratory for these carotenoids and participate in their quality assurance programme[28].

Physiological changes. The following physiological changes were measured: body weight, percentage body fat, blood pressure, plasma lipids and glucose and gastrointestinal symptoms. Body fat percentage was measured by a Quantum Bioelectrical Impedance Analyzer (body composition analysis; RJL System) at all three visits. Plasma total cholesterol, HDL-cholesterol, LDL-cholesterol and glucose were measured by finger stick using the Cholestech LDX System (Cholestech Corporation) with test cassettes. Upper gastrointestinal symptoms were assessed by a standard gastrointestinal tract symptom checklist[29], as TP are on the list of foods to avoid for lower oesophageal reflux. Briefly, the upper gastrointestinal symptoms questionnaire included questions about the severity of gastrointestinal symptoms during the last 4 weeks, rated 0–6, where 0 meant 'no complaints' and 6 represented the worst imaginable severity of that symptom.

Data analysis

With fifteen men per group, the estimate to detect differences between groups with a power of 80–97 %, $P<0·5$ were as follows: 22 % for plasma lycopene concentrations[30], 10 % for systolic and 12 % for diastolic blood pressure[31] and 22 % for plasma cholesterol concentrations[32]. The SAS statistical package (version 9.1; SAS Institute, Inc.) was used for all statistics. Differences in demographic and clinical characteristics

between the intervention group and the control group were assessed by using the χ^2 test for categorical variables or by using the *t* test for continuous variables. The monthly responses of each group (intervention and control) were compared. Endpoints not conforming to expected distributional assumptions were log transformed and noted accordingly.

Because all men in the intervention group met the *a priori* standard of 10 mg lycopene intake per d, we were unable to divide them into adherer and non-adherer groups as planned. Therefore, an arbitrary division point of 18 mg dietary lycopene per d (averaging the first 5 weeks of 24 h recalls during the intervention period) was used to divide the intervention group into moderately and highly adherent men for analysis of behaviour model characteristics. Due to small sample size, ANOVA was used to assess differences between moderately and highly adherent men in the intervention and control groups. Simple correlation or linear modelling was also used to explore factors that were associated with more or less adherence using three outcome variables: weekly servings of TP and dietary lycopene and plasma lycopene concentrations for the entire intervention group. All possible impediments and incentives from the weekly telephone calls were collected for the intervention group, then coded and frequencies by week were tabulated. The values are presented as means and standard deviations and statistical significance is based on a 95% CI ($P<0{\cdot}05$).

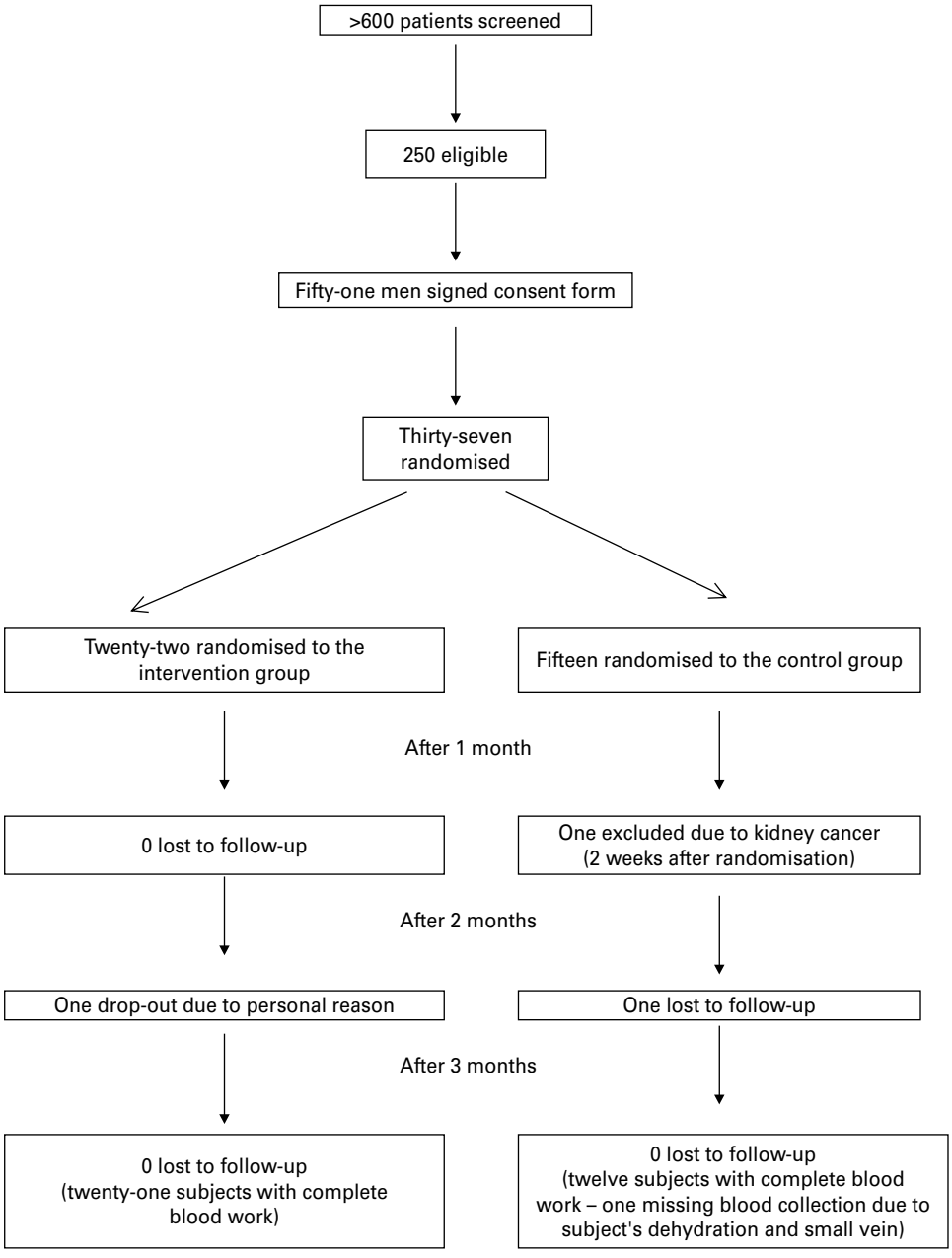


Fig. 1. Details of subject recruitment and withdrawal.

British Journal of Nutrition

Results

Participant characteristics

Of the fifty-one subjects who were enrolled at study entry, forty subjects (73%) who participated in the run-in period were randomised into the main study (Fig. 1). Table 1 shows descriptive statistics for clinical, demographic and behavioural variables. The mean age at study entry was 67·1 years (range 51–83 years). The intervention group mean body weight was significantly greater (94 kg) than the control group (81 kg) ($P=0·005$), and they had a higher BMI ($P=0·014$). The distribution between different categories of marital status was roughly the same for the groups, with the preponderance being married or single, living in households of mostly one or two people. This was reflected in who made decisions about food eaten and who did the shopping in the household. In all, 70% of the men considered that they exercised great autonomy in their own food choices and food shopping, as about 70% of both groups prepared their meals. Care with money spent for food (62%) and food insecurity (30%) were issues for a significant number of men in the present study. Over 73% of both groups had eaten out less than twice per week, which may be associated with a need to budget carefully because of limited money.

Table 1. Baseline characteristics of the study group

(Mean values and standard deviations; number of subjects and percentages)

	Intervention group (*n* 22)		Control group (*n* 15)	
Demographic characteristics	*n*	%	*n*	%
Age (years)				
Mean	66·2		68·4	
SD	7·2		7·44	
Serum PSA baseline (ng/ml)				
Mean	8·0		8·3	
SD	4·8		8·0	
Height (cm)				
Mean	177·9		174·8	
SD	8·5		5·2	
Weight (kg)				
Mean	93·9*		80·7	
SD	14·4		11·2	
BMI (kg/m^2)				
Mean	29·7*		26·4	
SD	4·3		3·1	
Marital status				
Married	8	36·36	7	46·67
Others	14	63·64	8	53·33
How many people in household				
≤ 2 People	17	77·27	11	77·33
> 2 People	5	22·73	4	26·67
Education				
≤ High school diploma	6	27·27	8	53·33
> High school diploma	16	72·73	7	46·67
Smoking experience				
Non-smoker	15	68·18	11	73·33
Current smoker	7	31·82	4	26·67
Physically active				
< 1 h/week	11	50·00	6	40·00
Over 1 h/week	11	50·00	9	60·00
Money security				
Limited money to purchase food	12	54·55	11	73·33
No limitation of food purchasing	10	45·45	4	26·67
Food security				
Enough food	15	68·18	11	73·33
Limited food	7	31·82	4	26·67
Meal cooking				
By myself	17	72·27	10	66·67
By other	5	23·73	5	33·33
Eat-out per week				
0	5	22·73	5	33·33
1	8	36·36	4	26·67
≥ 2	9	40·91	6	40·00
Food shopping				
Myself	14	63·64	11	73·33
Others	8	36·36	4	26·67
Menu choice				
Rare	5	22·73	4	26·67
Sometimes	5	22·73	2	26·67
Every time	12	54·55	9	60·00

PSA, prostate-specific antigen.

*There were significant group differences for body weight and BMI ($P<0·01$, $P<0·05$, respectively, *t* test). However, there were no significant group differences for any of the other variables ($P>0·05$, *t* test or χ^2 test).

Participation and reporting adherence

All subjects attended the orientation session to the study, a requirement for study participation. The mean of weekly telephone calls completed in the intervention group was 8·1 calls (67·5% completed, ranging from four to thirteen calls during the 3 months). The study goal was 80% completion (9·6 phone calls). Reasons for lower-than-expected phone completion rates in a few subjects were as follows: being out of town or phone service disconnected due to financial difficulty. In the control group, a mean of 4·4 bi-weekly telephone calls were completed (73%). The mean of collected 24 h recalls, including three during visits, was eleven recalls in the intervention group (ranged from seven to sixteen diet recalls) and 7·3 recalls in the control group (ranged from five to eleven diet recalls).

Mean lycopene intake throughout the study

As we gathered weekly diet recalls from the intervention group and bi-weekly diet recalls from the control group, we report monthly averaged nutrient intakes for the intervention and control group. Mean lycopene intake during the study period was 20·6 (SD 11·3) mg/d in the intervention group (424% increase from baseline intake, $P=0·0001$ for the between-group difference). There was also a mean increase in lycopene intake in the control group from 3·26 (SD 5·45) to 7·25 (SD 9·6) mg/d (122% increase from baseline intake), but the increase was not statistically significant (Table 2).

Weekly tomato product intake for the intervention group

Over 81% of the intervention group achieved the goal of more than five servings of TP/week (Table 2), increasing weekly TP intake from baseline values ($P<0·0001$) at 1 month, with no change in TP intake thereafter. The predominant TP chosen were V8 juice and tomato juice, according to weekly telephone reports (data not shown).

British Journal of Nutrition

British Journal of Nutrition

Table 2. Diet composition during the course of the study
(Mean values and standard deviations)

	Intervention group (*n* 21)						Control group (*n* 12)					
	Baseline		1 month		3 months		Baseline		1 month		3 months	
Dietary components	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Energy (kJ/d)	7360·9	1790·8	7285·2	1953·5	7687·3	2080·7	8940·8	2061·9	8803·6	2858·5	8927·4	3161·8
Carbohydrate (% energy)	39·4	8·8	47·5	8·0	46·5	6·9	46·9	11·9	47·4	9·1	42·5	6·0
Protein (% energy)	20·8	6·1	17·7	3·7	17·3	2·6	17·5	3·5	15·2	3·0	17·1	4·0
Fat (% energy)	38·9	6·1	35·3	7·4	36·6	6·6	35·6	10·3	37·2	6·0	40·7	5·5
Saturated fat (g/d)	24·8	10·9	23·1	11·4	24·7	11·9	28·6	12·2	29·1	11·7	35·4	25·6
Cholesterol (mg/d)	385·2	144·4	286·5	165·5	310·6	165·8	332·3	207·7	338·2	163·4	481·9	406·5
Lycopene (mg/d)***	3·93	5·73	21·96**	11·82	20·59**	11·27	3·26	5·45	6·37	7·49	7·25	9·64
α-Carotene (mg/d)	0·38	0·56	0·63	0·67	0·47	0·58	0·16	0·18	0·33	0·43	0·41	0·59
β-Carotene (mg/d)	3·61	4·01	3·02	2·61	3·86	2·76	1·16	0·84	2·69	2·30	5·35	8·15
β-Cryptoxanthin (mg/d)	0·11	0·17	0·12	0·12	0·17	0·17	0·13	0·19	0·14	0·14	0·17	0·21
Lutein + zeaxanthin (mg/d)	2·54	4·59	2·04	2·47	2·36	2·47	1·22	1·12	2·72	3·43	7·43*	1·33
Vitamin E (mg/d)	9·2	5·6	10·7	7·2	10·8	4·1	8·4	3·5	9·6	3·6	12·6	6·8
Tomato intake (servings/week)	3·5	3·2	6·0	1·3	6·1	2·1	Not measured		Not measured		Not measured	

Mean values were significantly different: * $P<0·05$.
Mean values were significantly different for lycopene intake within-group comparison: ** $P<0·0001$.
Mean values were significantly different for lycopene intake between-group comparison over time: *** $P<0·0001$.

Plasma lycopene, other carotenoid and tocopherol concentrations over the 3-month period

The adherence goal of a 50 % increase in plasma lycopene concentration from baseline was met by the intervention group at 1 month (53 %, $P=0·0028$) but not at 3 months (40 %, $P=0·0162$). The decline between 1 and 3 months (8·7 % decrease) was not statistically significant, and the overall increase was statistically significant ($P=0·0013$, Table 3). There was no control group increase in plasma lycopene concentration over the 3-month period. Association of reported lycopene intake in the intervention group with plasma lycopene levels was stronger at 1 (r 0·43, $P=0·01$) and 3 months (r 0·41, $P=0·02$), compared with baseline (r −0·05, $P=0·80$). The mean biological half-life of lycopene in circulation using the most rigorous estimates ranges from 3 to 5 d; hence, consistent consumption of TP during the intervention by the intervention group probably strengthened these associations[33,34].

Plasma carotenoids, other than lycopene, α-carotene and β-carotene concentrations (contained in TP), did not increase in the intervention group. Although there was a self-reported increase in dietary lutein + zeaxanthin in the control group, there were no changes in any of the plasma concentrations of carotenoids. If there had been increased intake of other fruits and vegetables in either group, as recommended as part of the AICR pamphlets, plasma concentrations of the other carotenoids, especially lutein + zeaxanthin, should have risen.

Factors associated with adherence to increased tomato product intake

Table 4 presents mean scores for behavioural factors often assessed as part of the social cognitive model, separately for highly and moderately adherent men in the intervention group, compared with the control group men. These behavioural factors were assessed before the intervention commenced, but all men had received their team assignment and had just viewed the orientation PowerPoint presentation designed for their respective group. While all groups scored high on knowledge of PC health and beliefs concerning foods that had been associated with reduced risk of cancer, the control group perceived more difficulty in adhering to their diet prescription, as measured by lower scores on the ease of adherence scale and higher scores on barriers to adherence scale compared with either intervention subgroup. Furthermore, barrier scores (e.g. storage, purchase effort, preparation issues, expense issues, not in usual diet, etc.) for the intervention group men were negatively associated with their 1- and 3-month plasma lycopene concentrations (r −0·37, $P=0·024$) and dietary lycopene (r −0·49, $P=0·022$). The TP intake disadvantage score (e.g. too filling, unpleasant taste, intestinal discomfort, etc.) was also negatively associated with 3-month plasma lycopene concentrations (r −0·37, $P=0·008$).

Intervention-related incentives and impediments

Throughout the intervention period, men responded to open-ended questions concerning their incentives and

Table 3. Physiological responses and upper gastrointestinal symptoms (UGIS)
(Mean values and standard deviations)

	Intervention group (*n* 21)						Control group (*n* 12)					
	Baseline		1 month		3 months		Baseline		1 month		3 months	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Physiological responses												
Plasma lycopene (μmol/l)***	0·45	0·22	0·69**	0·3	0·63**	0·4	0·45	0·24	0·41	0·2	0·41	0·2
Plasma α-carotene (μmol/l)	0·05	0·04	0·07*	0·05	0·06*	0·05	0·06	0·05	0·05	0·04	0·05	0·03
Plasma β-carotene (μmol/l)	0·25	0·24	0·34*	0·23	0·28	0·25	0·32	0·25	0·27	0·19	0·29	0·24
Plasma β-cryptoxanthin (μmol/l)	0·11	0·06	0·15	0·08	0·14	0·06	0·15	0·14	0·12	0·1	0·10	0·08
Plasma lutein + zeaxanthin (μmol/l)	0·36	0·16	0·40	0·20	0·37	0·20	0·31	0·15	0·33	0·17	0·37	0·18
Plasma α-tocopherol (μmol/l)	27·29	9·53	28·52	7·91	26·93	8·53	27·47	10·3	27·6	15·5	24·07	7·99
Plasma γ-tocopherol (μmol/l)	5·22	3·08	5·11	3·16	5·70	2·89	4·62	3·7	4·56	2·90	4·76	2·54
Plasma retinol (μmol/l)	1·22	0·51	1·64*	0·55	1·48*	0·67	1·29	0·54	1·17	0·43	1·22	0·57
Total cholesterol (mg/l)	1867	588	1762	387	1714	658	1886	381	1699	287	1708	331
Vital signs												
Systolic blood pressure (mmHg)	132·6	14·8	130·8	18·1	130·1	13·7	127·2	25·4	131·5	23·5	126·2	24·5
Diastolic blood pressure (mmHg)	76·8	9·3	76·6	11·4	75·9	8·3	80·1	10·4	77·0	10·0	75·3	10·1
Body weight (kg)	94·2	15·2	93·5	15·7	92·9	16·8	79·0	12·2	79·5	12·8	79·9	13·6
UGIS†												
Epigastric pain	0	0	0·03	0·1	0·1	0·2	0·1	0·2	0·2	0·3	0·2	0·4
Abdominal pain	0·2	0·1	1·1	0·2	0·1	0·3	0·3	0·2	1·3	1·1	0·2	0·1
Heartburn	0·2	0·5	0·3	0·7	0·2	0·4	0·4	0·6	0·3	0·6	0·2	0·4
Regurgitation	0·1	0·3	0·1	0·3	0·2	0·4	0·1	0·4	0·2	0·4	0·2	0·6
Bloating	0·5	0·8	0·7	1·0	0·5	0·7	0·5	0·7	0·5	0·7	0·5	0·8
Belching	0·7	0·7	0·6	0·7	0·6	0·7	0·7	0·7	0·6	0·7	0·7	0·7

Mean values were significantly different for within-group comparisons: * $P<0·05$, ** $P<0·001$.
Mean values were significantly different for plasma lycopene between-group comparison: *** $P=0·005$.
† UGIS were scored 0–6, where 0 meant 'no complaints' and 6 represented the worst possible severity of that symptom.

Table 4. Scores of behaviour model components by lycopene intake of highly and moderately adherent intervention participants and control participants

(Mean values with their standard errors)

	Intervention ≥ 18 mg/d (*n* 13)†		Intervention ≤ 18 mg/d (*n* 8)		Control (*n* 12)	
Dietary lycopene and behaviour scores	Mean	SEM	Mean	SEM	Mean	SEM
Mean dietary lycopene‡						
Baseline (mg/d)	9·4	3·1	5·9	2·0	6·5	2·9
1–5 weeks (mg/d)	27·2	2·7	13·4	1·3	6·0	1·7
Dietary cancer prevention belief scores (eleven-item scale, 1–5 points/item: descriptor = agreement)	3·95	0·18	3·89	0·14	3·71	0·20
Prostate cancer health belief scores (eight-item scale, 1–5 points/item: descriptor = agreement)	4·28	0·15	4·22	0·18	3·76	0·28
Perceived ease of adherence to diet prescription (1–5 points: descriptor, 3 = neutral, 4 = easy, 5 = extremely easy)	4·62	0·14	4·50	0·19	3·08 **	0·31
Intention to adhere to diet prescription (1–5 points: descriptor, 4 = will try, 5 = definitely will)	5·00	0	5·00	0·13	4·90	0·15
Perceived advantages of adherence (nine-item scale, 1–5 points/item: descriptor = importance)	4·24	0·24	4·07	0·45	4·19	0·22
Perceived disadvantages of adherence (six-item scale, 1–5 points/item: descriptor = importance)	3·02	0·34	3·19	0·40	3·61	0·31
Personal barriers to adherence (ten-item scale, 1–5 points/item: descriptor = importance)	2·09	0·39	2·70	0·27	3·30*	0·29
Social support score (eight-item scale, 1–5 points/item; descriptor = support)	3·84	0·24	3·56	0·43	3·36	0·25

Mean values between-group were significantly different for the control group: * $P = 0{\cdot}04$, ** $P \leq 0{\cdot}0001$.

† Intervention group was divided into highly and moderately adherent men using a dietary lycopene cut point of 18 mg/d averaged over the first 5 weeks of the intervention.

‡ Mean of four baseline 24 h diet recalls and mean of five weekly 24 h diet recalls during intervention period.

impediments. The orientation session appeared to be motivational, as many of the intervention group subjects mentioned it to be the source of their adherence. Many of the intervention group subjects volunteered that they liked the newsletter and tried to cook tomato dishes from newsletter recipes (fourteen responded out of twenty-four subjects, 58 %). Although both control and intervention groups were introduced to the AICR cancer prevention diet during their orientations and by the AICR booklets, no specific or ongoing counselling was provided for this dietary change.

The incentives for TP consumption tended to be consistent from one call to the next for each participant. Most subjects reported the consumption of a TP on their 24 h diet recall, and weekly consumption mostly met the goal of more than five servings per week; hence, weekly goal setting based on reported impediments was not necessary. Table 5 presents the weekly frequency of self-reported incentives and impediments to the previous day's consumption of a TP, collected as part of the 24 h diet recall process. Concern over prostate health was the most consistent, and remained the most predominant incentive throughout the study. Although many men volunteered that they liked tomatoes at the beginning of the study, this incentive abruptly decreased after week 6, as well as another incentive, study participation, which dropped by week 9. Family member support (principally wives) was an important incentive for a few men, especially in the middle of the study. The media exposure was described as a segment by Dr Oz on the Oprah Winfrey Show that featured tomato

Table 5. Frequency of self-reported incentives and impediments to previous day's consumption of tomato products (TP) by men in the intervention group

	Incentives					Impediments		
Week	Prostate health	Like tomatoes	Study participant	Social support	Media exposure	Cupboard bare of TP	Forgot	Poor appetite
1	6	7	6	4	0	2	0	0
2	9	8	7	1	1	1	0	0
3	9	5	5	1	1	2	0	1
4	9	7	3	1	1	2	0	0
5	8	4	2	6	1	0	1	0
6	9	5	4	3	3	2	0	1
7	10	2	6	3	1	0	1	0
8	7	3	6	3	0	0	1	0
9	10	1	2	3	0	1	1	0
10	10	1	1	2	0	1	0	0
11	9	1	1	1	0	0	1	0
12	5	0	2	0	0	1	1	0

consumption for the prevention of PC. The number of cited impediments was much lower than reported incentives, because there were far fewer occasions when the men had not consumed a TP on the day when the 24 h recall was taken. TP availability at the time of food preparation and forgetting are likely to play an important role in a larger, less-adherent group of men.

Adverse effects of eating daily tomato products

A common belief that dishes containing TP cause gastric distress and increase in Na, saturated fat and cholesterol intake, leading to higher blood pressure and plasma cholesterol, prompted us to explore these issues, as well as diet displacement caused by the aggressive inclusion of a single food class.

Dietary nutrient displacement

Energy intake for the intervention group was surprisingly lower than the control group throughout the study period (Table 2). However, there were no statistically significant changes within and between groups over the 3-month period ($P=0{\cdot}883$). As the intervention group had higher BMI and percentage body fat and reported lower exercise levels, a combination of lower energy needs and probably greater underreporting of food intake could have contributed to the discrepancy. As energy intakes were different for the intervention and control groups, diet quality was assessed after energy adjustment. The intervention group did not increase saturated fat intake ($P=0{\cdot}10$) or cholesterol intake ($P=0{\cdot}002$), which showed a downwards trend, compared with the control group over the 3-month period (Table 2). Changes in food-based, non-discretionary Na intake are not shown because of validity concerns[35], although intakes averaged over double the recommended Na requirement[36] for both groups.

Physiological parameters

As noted previously, the intervention group had a higher mean body weight at the beginning of the study and maintained this difference throughout. They experienced a slight decrease in body weight by 3 months, but the change was statistically insignificant (Table 3). There was no difference in total plasma cholesterol concentration between the intervention and control group at any time point, i.e. at 1 and 3 months ($P=0{\cdot}51$ and 0·81, respectively). Total plasma cholesterol concentration decreased within each group over the 3-month period, but the decrement in the intervention group was uncertain ($P=0{\cdot}061$). There were no changes in systolic blood pressure and diastolic blood pressure for either group over the course of the study (Table 3).

Although the present study was not sufficiently powered to determine that no changes occurred in blood pressure and plasma cholesterol concentrations, the null results are consistent with the dietary reports.

Gastrointestinal symptoms

There were no between-group differences in upper gastrointestinal symptoms. Both groups initially reported an increase in abdominal pain at 1 month ($P=0{\cdot}06$), but it appeared to be resolved by 3-months of the study ($P=0{\cdot}18$, Table 3).

Discussion

The present preliminary study demonstrated that AA men with low socio-economic status at risk for PC increased their lycopene intake through a self-selected diet by four-fold (to 20·6 mg/d) during a 3-month period. Plasma lycopene concentrations in the intervention group rose from 0·45 to 0·69 μmol/l (53 % increase) at 1 month, which was consistent with their self-reported intake, and the slight decrement (to 0·63 μmol/l) at 3 months mirrored their reported decrement in lycopene intake at 3 months. Baseline plasma lycopene values were similar to those reported in other studies, e.g. for AA men (from 0·27 to 0·41 μmol/l), regardless of ethnicity (from 0·22 to 0·73 μmol/l)[37–44]. As expected, this plasma lycopene increment was not as great as we reported for mostly AA men with PC recruited from the same clinic, who received 30 mg/d of lycopene as daily tomato pasta entrées for 3 weeks before surgery (0·64–1·26 μmol/l; 97 % increase)[20]. The control group reported progressive increases in dietary carotenoids (lycopene 122 %, NS and β-carotene 361 %, $P=0{\cdot}09$) and lutein + zeaxanthin (509 %, $P=0{\cdot}01$) (Table 2), while there was no rise in their plasma carotenoids (Table 3), indicating a possible intention to increase fruit and vegetable intake, as prescribed by the AICR diet. The intervention group reported no dietary increase in carotenoids other than lycopene. Even though they also were encouraged to follow the AICR diet, they chose to focus on the TP assignment. Parsons *et al.*[45] promoted increased fruit and vegetable consumption via telephone-based counselling to forty-three PC patients and found the following 6-month increments in plasma carotenoids: α-carotene 37 %, β-carotene 32 %, lutein + zeaxanthin 23 %, lycopene 30 % (despite a reported 265 % increase in TP intake) and total carotenoids 25 %. The AICR cancer prevention diet prescription may have been too complex to adopt without specific counselling in our group of men.

We explored the effects of social cognitive model domains for behaviour change on the level of adherence within and between the two groups, using lycopene intake, TP intake and plasma lycopene concentrations as measures of adherence. The usual factors such as knowledge, intention and self-efficacy were less predictive in our subjects, because all scored highly on these scales, possibly because they all had just experienced a well-received presentation that outlined prostate health and dietary factors for cancer prevention. The most predictive of subsequent adherence were scales that explored the importance of various barriers to adherence, along with a list of disadvantages as a separate scale. Not only did the control group have higher scores on these scales, the intervention group scores were inversely correlated with their lycopene intake and plasma lycopene concentrations.

British Journal of Nutrition

Carcaise-Edinboro *et al.*[46] promoted, through pamphlets and a few telephone calls, a cancer prevention diet, in 754 low-income, low-literacy patients, of whom 36·8% were African-American. Despite a two-fold increase in knowledge and intention to increase fruit and vegetable consumption among AA men and women, their diets did not change. Many investigators have concluded that understanding specific barriers in each population and actively addressing them should improve adherence[47–51].

We proposed that incentives and impediments to adherence would arise in the context of now-time decision making, would be temporally unstable and so could be better remembered for the previous day. These were assessed only in intervention subjects at the time of their 24 h recalls. Incentives predominated over impediments, because most of the intervention subjects adhered to their diet prescription with respect to TP consumption, and incentives were remarkably stable from week to week. However, liking tomatoes and study participation lost their incentive appeal by the sixth and ninth week of the study, respectively, while prostate health remained important throughout the study. The only study that evaluated dietary pre- and post-intervention shifts in barriers was a Scottish fruit and vegetable intervention[52]. The number of visits to stores became a more prominent barrier during the intervention, while other barriers became less important[52]. Two exercise intervention studies also found shifts in barrier importance and type as the interventions proceeded[53,54].

We found few diet shifts or adverse effects resulting from a fairly large increase in TP consumption in the intervention group. Energy under-reporting was evident in the intervention group men who had higher BMI, a commonly reported finding[55,56]. We chose to display reported energy intakes instead of using the classical Goldberg adjustment[57] because: (1) several of our subjects in each group indicated limited food supply (32% intervention, 27% control; Table 1); (2) an inspection of individual recalls for 'under-reporters' showed consistently low intakes or sporadically very low intakes on single days; (3) we were interested in changes in TP and fruits and vegetables rather than the foods that are usually forgotten, such as snacks. Our personal experience with this population is that food shortages are often temporary and may not be reflected in BMI. An exploration of those who lost weight during the study could not explain reported low energy intakes.

We saw no change in both systolic and diastolic blood pressure. A total of fifteen subjects in our intervention group were being treated for hypertension and they often forgot to take their medication. Contrary to the common advice to avoid TP to minimise gastric complaints, upper gastrointestinal symptoms did not change over the time of the study.

The present feasibility study had some limitations. First, the number of phone calls and collected diet recalls between groups was different because of the concern that the control group would increase their TP intake. As there was a negligible 'drop-in' effect in the control subjects, the number of contacts could be equalised in a larger study. Second, the sample size was small and groups were unequal in number to account for an estimated non-adherence rate of 40% in the intervention group. This rate was estimated from adherence rates in published fruit and vegetable intervention studies[58–66]. As our AA participants were mostly successful in increasing their TP intake, we gained little insight into the impediments encountered in affecting a simple diet change.

Conclusions

The present study demonstrated that low-income AA men, who are at higher risk for PC, can successfully achieve their TP adherence goal with a corresponding rise in plasma lycopene concentrations. Increased TP consumption did not increase dietary cholesterol or saturated fat, which was consistent with no increase in blood pressure or plasma total cholesterol concentration. Although the control group had the same risk for PC and knew of the tomato intervention, they did not voluntarily 'drop-in' to the intervention arm of the study, while the intervention group appeared to ignore the AICR diet in favour of the single food recommendation.

The present whole-food intervention was sufficiently simple for successful participant adherence and enabled the determination of incentives and impediments to previous day compliance, while memories were fresh. Incentives, for the most part, were temporally stable, although the stability of impediments requires further investigation. The disadvantage and barriers category of the environmental domain of the social cognitive theoretical model of behaviour change was the most predictive of adherence, with the control group perceiving greater difficulty in adhering to the AICR diet recommendation In conclusion, single-food intervention studies may provide greater understanding of the dynamics of dietary adherence as well as improve adherence, both for longer intervention studies and as a strategy for achieving health-promoting dietary patterns.

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British Journal of Nutrition

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