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Quality of life and self-rated health in relation to changes in fruit and vegetable intake and in plasma vitamins C and E in a randomised trial of behavioural and nutritional education counselling

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We have carried out a randomised trial comparing brief behavioural counselling with nutritional education counselling to increase fruit and vegetable consumption and associated biomarkers in adults from a low-income neighbourhood. The objective of the present analysis was to assess the impact of interventions on quality of life and health status, and associations between changes in fruit and vegetable consumption, plasma vitamins C and E, and quality of life. Behavioural counselling and nutritional education counselling were carried out in 271 adults in two 15 min sessions in a primary-care setting. Physical and mental health status (medical outcome study short form 36) and self-rated health were assessed at baseline, 8 weeks and 12 months, and analysed on an intention-to-treat basis. Both groups reported increased fruit and vegetable consumption; plasma vitamin E and β-carotene also increased, with significantly greater changes in consumption and plasma β-carotene in the behavioural counselling condition. Physical and mental health status, and the proportion of participants in good self-rated health, increased in both groups to a similar extent. Individual differences in improvements in physical health status and self-rated health were correlated with increases in fruit and vegetable intake and in plasma vitamins C and E, independently of age, gender, ethnicity, financial status, smoking, BMI and use of vitamin supplements. We conclude that participation in the present study was associated with improved health-related quality of life. Increases in fruit and vegetable intake and plasma vitamin levels may stimulate beneficial changes in physical health status in socio-economically deprived adults.

Dietary counselling: Quality of life: Plasma vitamins: Fruits and vegetables: Socio-economic status

Increasing fruit and vegetable consumption is a major objective of health-promotion programmes worldwide (World Health Organization, 2002; Department of Health, 2003). Consumption is greater in higher socio-economic status groups, so increasing intake in lower income sectors may help reduce socio-economic disparities in health (Henderson *et al.* 2002). We have recently conducted a randomised controlled trial comparing brief behavioural counselling and nutritional education counselling in a primary-care setting in a low-income, ethnically mixed neighbourhood. Increases in fruit and vegetable consumption over 12 months were reported by both groups, and were corroborated by changes in plasma β-carotene and vitamin E (Steptoe *et al.* 2003*a*). The increases in intake and in plasma β-carotene were significantly greater following behavioural counselling after adjusting for gender, age, income, ethnicity, smoking status and baseline stage of change.

An important issue in evaluating interventions is whether they have adverse effects on quality of life, despite being efficacious for the target health problem. Quality of life evaluations are conventional in pharmaceutical trials, but have been included less often in dietary studies. This situation has changed in recent years, and several interventions with dietary components have incorporated quality of life measures into their assessment batteries (Plaisted *et al.* 1999; Corle *et al.* 2001; Pierce *et al.* 2002; Toobert *et al.* 2002; Miller *et al.* 2003). It cannot be assumed that dietary interventions are free of adverse effects on quality of life and health status. There were fears 10 years ago that cholesterol-lowering through fat reduction might induce depressive mood (Muldoon *et al.* 1990), although subsequent trials allayed these concerns (Muldoon *et al.* 2001). Changes in digestive symptoms that could adversely affect quality of life have been reported with increased fruit and vegetable intake (Smith-Warner *et al.* 2000). In addition, it is possible that attempts to change eating habits in social settings may lead to embarrassment and negative social interactions (Steptoe *et al.* 2003*b*). The first aim of the present analysis was, therefore, to evaluate the effects of participation in behavioural or nutritional

Abbreviation: SF-36, medical outcome study short form 36.

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education counselling for increasing fruit and vegetable intake on health-related quality of life and self-rated health.

We were also interested in whether changes in fruit and vegetable intake and in biomarkers such as plasma vitamin C, vitamin E and β-carotene were associated with changes in health status. It has been claimed that vitamin supplementation positively affects subjective well-being (Benton *et al.* 1995), although this has not been replicated consistently (Barringer *et al.* 2003). Inverse associations between plasma or serum vitamin E and depressive symptoms have been reported in some studies, but not all (Shibata *et al.* 1999; Maes *et al.* 2000; Tiemeier *et al.* 2002). Vitamins C and E are thought to have favourable effects on neural function and cognitive performance, but the evidence is again inconsistent (Paleologos *et al.* 1998; Martin *et al.* 2002; Morris *et al.* 2002). The second aim was to test whether changes in reported fruit and vegetable intake and in biomarkers over 8 weeks and 12 months were associated with health status assessed using the medical outcome study short form 36 (SF-36) and measures of self-rated health.

Methods

Participants

Men and women (*n* 271) aged 18–70 years were randomly recruited from the patient registers of a primary-health centre in South London (Steptoe *et al.* 2003*a*). The health centre is in a deprived inner-city area. Individuals with serious illnesses and women who were pregnant or planned to become pregnant within the next 12 months were excluded. A total of 459 patients expressed interest in the study, but 188 were excluded on these criteria or because they were found on later enquiry to have high incomes.

Study design

This parallel-group randomised trial compared brief behavioural dietary counselling with nutritional education counselling matched for professional contact time (Steptoe *et al.* 2003*a*). Recruitment, assessments and interventions were carried out by research nurses. The interventions were delivered in two 15 min individual counselling sessions carried out at a 2-week interval, supported by written information. Assessments, including reported fruit and vegetable intake, plasma measures of β-carotene, vitamin E (α-tocopherol) and vitamin C (ascorbic acid), were performed at baseline before randomisation, and after 8 weeks and 12 months. We assessed quality of life at baseline, 8 weeks and 12 months. The study was approved by the Wandsworth Local Research Ethics Committee.

Counselling methods

The nutrition education counselling group received education about the importance of increasing consumption, emphasising the beneficial effects of nutritional constituents and the way these act biologically to maintain health. The bioactive constituents of fruits and vegetables were described in lay terms, together with the range of effects that they have on body processes. The recommendation from the UK Department of Health (2003) to eat five portions of a variety of fruits and vegetables per d was emphasised. The behavioural counselling included abbreviated nutritional education, but in addition involved counselling founded on social learning theory and the stage of change model, so methods of encouraging behaviour change varied with the motivational readiness of the individual (Hunt & Hillsdon, 1996; Prochaska & Velicer, 1997). Readiness to change, dietary knowledge and perceived barriers were assessed, so that counselling could be tailored to the individual. Thus, the counselling for an individual who was not convinced of the benefits of fruit and vegetable consumption emphasised attitude change, while counselling for those ready to change focused on specific behavioural goals and the practical implementation of change. Social reinforcement was used to foster self-efficacy for change and the attainment of short-term and long-term goals. Written material addressed common barriers to change, and suggested ways of overcoming these. Both of the research nurses conducted nutritional and behavioural counselling after training from experienced behavioural scientists, and sessions were audio-taped to monitor the quality of interventions.

Measures

We measured fruit and vegetable consumption with a two-item frequency questionnaire adapted from previous research (Wardle *et al.* 2000). Participants were asked how many servings of fruits and how many portions of vegetables they ate on a typical day, and were given detailed information about portion sizes. Potatoes were excluded, as is standard practice in UK research, and one serving of fruit juice was included. This measure was validated against plasma and urinary biomarkers of fruit and vegetable intake at baseline, with evidence that self-reported fruit intake was correlated with plasma levels of vitamin C and β-carotene and with urinary K excretion, while fruit and vegetable intake was associated with plasma vitamin C and K excretion expressed as total daily excretion and as the K:creatinine ratio (Cappuccio *et al.* 2003).

Quality of life was assessed using the SF-36 health status measure, adapted slightly for use in the UK (Ware & Sherbourne, 1992; Jenkinson *et al.* 1996). The SF-36 assesses eight domains of health-related quality of life: physical function; role limitations due to physical problems; role limitations due to emotional problems; social functioning; general mental health; vitality; pain; general health perceptions. Each domain is scaled so that 0 represents the lowest and 100 the highest possible level of function. Scores for the eight domains at baseline were calculated. We evaluated change in quality of life by following the procedure advocated by Ware *et al.* (1994) of calculating physical health and mental health status summary measures. Physical health status is calculated by averaging scores on physical function, role limitations due to physical problems, pain and general health perception measures, while mental health status is calculated by averaging scores on the role limitations due to emotional problems, social functioning, general mental health and vitality measures.

Self-rated health was assessed with a single item: ‘In general, would you say your health is excellent/very good/good/fair/poor'. Simple measures of this type have been shown to predict health status and mortality in a large number of studies (Idler & Benyamini, 1997) and are suitable across the socio-economic gradient (Burstrom & Fredlund, 2001).

Non-fasting venous samples were analysed to determine plasma vitamin C (ascorbic acid), vitamin E (α-tocopherol) and β-carotene. Blood for vitamin C analysis was collected in citrate, protected from light, cold spun and plasma added to metaphosphoric acid (100 ml/l). Levels were estimated using a fluorometric assay (Vuilleumier & Keck, 1989). Vitamin E and β-carotene were measured concurrently by normal-phase HPLC (Armstrong *et al.* 1997).

Procedure

The patients who agreed to take part in the study completed baseline quality of life measures before attending an individual assessment session in the health centre. Information concerning ethnicity, marital status, educational attainment, income, smoking status, stage of readiness for change and vitamin supplements was obtained by questionnaire. At the assessment session, fruit and vegetable intake was recorded, blood samples were drawn, and anthropometric measures and a medical history were obtained. Randomisation took place after the baseline assessment using a minimisation procedure to ensure a balance across groups in age, gender, ethnic background and smoking (Treasure & MacRae, 1998). The first 15 min counselling session followed immediately, and the second counselling session 2 weeks later. A third 15 min encouragement and support session was scheduled after 6 months. Measures of fruit and vegetable intake, biomarkers and quality of life were repeated 8 weeks after the baseline and then after 12 months.

Statistical analysis

The 8-week assessment was completed by 245 (90·4 %) of participants, and the 12-month assessment by 218 (80·4 %). The number of people who failed to complete follow-up assessments did not differ between groups. All analyses were carried out on an intention-to-treat basis, including data from all participants entered into the trial, irrespective of whether they completed all assessments or dropped out of the study. We assumed no change in individuals who did not complete follow-up assessments, so carried forward the baseline measure for missing data at 8 weeks and 12 months. Data on fruit and vegetable intakes were available from all 271 participants, β-carotene from 268 (99 %), vitamin E from 266 (98 %) and vitamin C from 265 (98 %).

The attributes of the behavioural counselling and nutritional education counselling groups at baseline were compared by ANOVA and χ^2 tests as appropriate. Financial status was categorised according to whether income was greater than or less than £400 per week. This is less than the national average gross income of £480 per week in 1999–2000, and close to the average for lower socio-economic status employment categories (Down, 2000). Of the participants, 177 of 271 (65 %) fell into the lower income category. SF-36 ratings for all eight health status domains. as well as summary physical and mental health scales. were compared between groups and also with the values obtained in the Oxford Healthy Life Survey (UK population survey of 13 042 randomly selected men and women aged 18–64 years; Jenkinson *et al.* 1993). Self-rated health was divided into fair or poor health, and good health or better.

We analysed changes in quality of life over the trial using repeated measures ANOVA of physical health and mental health status summary scores, and the proportion of people who rated their health as good or better. These analyses included group (behavioural, nutritional education counselling) and gender as between-subject factors, and time (baseline, 8 weeks, 12 months) as the within-subject factor. The Greenhouse–Geisser correction was applied when appropriate and *post hoc* comparisons were carried out using Fisher's least significant difference procedure.

Associations between predictors (fruit and vegetable consumption and biomarkers) and physical and mental health status summary measures were analysed with a series of multiple regressions. These regression analyses included covariates that we have previously identified as related to changes in reported consumption and biomarkers (Steptoe *et al.* 2003*a*). In the analyses involving fruit and vegetable consumption, the covariates were age, gender, ethnicity (coded as a binary variable), financial status (coded as higher or lower income), smoking status (binary variable) and BMI (continuous variable). In the analyses involving biomarkers, the covariates included these factors plus use of vitamin supplements. Unstandardised linear regression coefficients for the predictor variables of interest (fruit and vegetable consumption, vitamin C, vitamin E or β-carotene) adjusted for covariates are presented with 95 % CI. We analysed changes in self-rated health by calculating whether there had been a shift from fair or poor health to good or better health between baseline and 8 weeks or 12 months. These data were analysed using logistic regression, and odds ratios with 95 % CI are presented.

Results

The attributes of participants in the two groups at baseline are summarised in Table 1. Overall, 61·3 % of participants were women, with no gender difference between groups. About one-third came from ethnic minorities, predominantly black African and black Afro-Caribbean. Two-thirds were below the low-income criterion, with one-third being in receipt of welfare benefits. There were no differences between groups in any of these characteristics or in BMI, smoking habits or the proportion using vitamin supplements. The treatment groups did not differ in fruit and vegetable consumption or in biomarkers at baseline. The SF-36 indicated only moderate functioning in all domains, and 22·5 % were in poor or fair health. Average SF-36 ratings were significantly below those of the previously published population survey in all eight domains ($P<0·001$).

Responses to the interventions

The effects of behavioural and nutritional education counselling have been detailed elsewhere, so only summary results will be presented (Steptoe *et al.* 2003*a*,*b*). The number

Table 1. Attributes of the behavioural and nutritional counselling groups at baseline
(Mean values and standard deviations)

	Behavioural counselling (*n* 136)		Nutritional education counselling (*n* 135)	
	Mean	SD	Mean	SD
Men/women (*n*)	54/82		51/84	
Age	43·3	13·8	43·2	14·0
Ethnicity:				
White*	94	70·1	96	72·2
Black*	37	27·6	32	24·1
Asian*	3	2·2	5	3·8
Household income <£400 per week*	91	69·5	86	66·2
In receipt of welfare benefits*	50	37·3	43	32·8
BMI	25·5	4·9	26·3	5·8
Current smokers*	47	34·6	44	32·6
Taking vitamin supplements*	40	32·3	38	30·4
Portions of fruit and vegetables (*n* per d)	3·67	2·00	3·60	1·81
Plasma vitamin C (μmol/l)	78·0	33·0	75·6	33·3
Plasma vitamin E (μmol/l)	27·4	10·9	25·6	11·3
Plasma β-carotene (μmol/l)	0·92	0·68	0·90	0·62
SF-36				
Physical function	82·2	22·7	81·6	24·1
Physical role limitations	76·0	37·6	73·7	36·8
Emotional role limitations	71·8	38·7	70·0	37·2
Social functioning	80·8	21·9	79·4	23·4
General mental health	68·7	18·0	67·1	17·6
Vitality	55·8	21·0	53·1	20·8
General health perceptions	62·6	22·4	65·0	21·6
Pain	71·5	25·2	73·0	23·7
Physical health	73·1	22·1	73·3	20·9
Mental health	69·2	21·1	67·4	20·3
Self-rated health good or better*	104	76·4	105	77·7

SF-36, Medical outcome short study form 36 (Ware & Sherbourne, 1992; Jenkinson *et al.* 1996).
* *n* and %.

of portions of fruits and vegetables consumed per d increased over 12 months by 1·49 (95 % CI 1·12, 1·86) in the behavioural counselling group and by 0·87 (95 % CI 0·50, 1·25) in the nutritional counselling group, a mean difference of 0·62 (95 % CI 0·09, 1·13; $P<0·05$) adjusted for gender, age, ethnicity, income, smoking and baseline stage of change. The proportion of participants consuming five or more portions per d increased by 42·2 (95 % CI 33·1, 51·2) % in the behavioural counselling group and 26·8 (95 % CI 17·6, 36·0) % in the nutritional counselling group (difference 15·4 (95 % CI 2·5, 28·3) %, $P<0·05$). The plasma concentration of vitamin E increased over 12 months in both groups (mean values 8·81 (95 % CI 7·1, 10·5) and 7·30 (95 % CI 5·58, 9·02) μmol/l for behavioural and nutritional counselling groups respectively), with no difference between the groups. There were also increases in β-carotene in both groups (mean values 1·20 (95 % CI 1·08, 1·33) and 1·04 (95 % CI 0·94, 1·15) μmol/l respectively), with a larger increase in the behavioural counselling group (mean difference 0·16 (95 % CI 0·001, 0·340) μmol/l, $P<0·05$). Plasma vitamin C did not change in either group over the 12-month study period.

Changes in quality of life over the study

There was a main effect of time ($P<0·001$), but no group or gender differences in the analysis of the physical health status summary measure (Fig. 1). Physical health status increased between baseline and 8-week assessments ($P<0·001$), and remained elevated at 12 months in both groups ($P<0·001$). There was no change between 8 weeks and 12 months. A similar pattern was observed for the mental health status summary measure, with a significant change over time ($P<0·001$) due to increases between baseline and 8 weeks (Fig. 1). The behavioural and nutritional education counselling groups did not differ in the magnitude of increases.

The proportion of participants who reported that their health was good, very good or excellent increased over time from an average of 77·1 % at baseline to 83·1 % after 8 weeks and 82·3 % after 12 months ($P<0·01$). *Post hoc* tests indicated that the proportion in good or better health differed between baseline and 8 weeks ($P<0·05$) and between baseline and 12 months ($P<0·05$), but not between 8 weeks and 12 months (Fig. 2). This pattern did not differ between groups, and there were no gender differences at any point.

Fruit and vegetable intake and quality of life

Baseline levels of fruit and vegetable consumption were positively associated with physical health status and mental health status summary scores, but not with self-rated health. The regressions of fruit and vegetable intake *v.* physical health status (B 1·45 (95 % CI 0·13, 2·77), $P<0·05$) and mental health status (B 1·47 (95 % CI 0·16, 2·78), $P<0·05$) were independent of age, gender, ethnicity, income, smoking and BMI. Self-rated health at baseline was not associated with fruit and vegetable consumption.

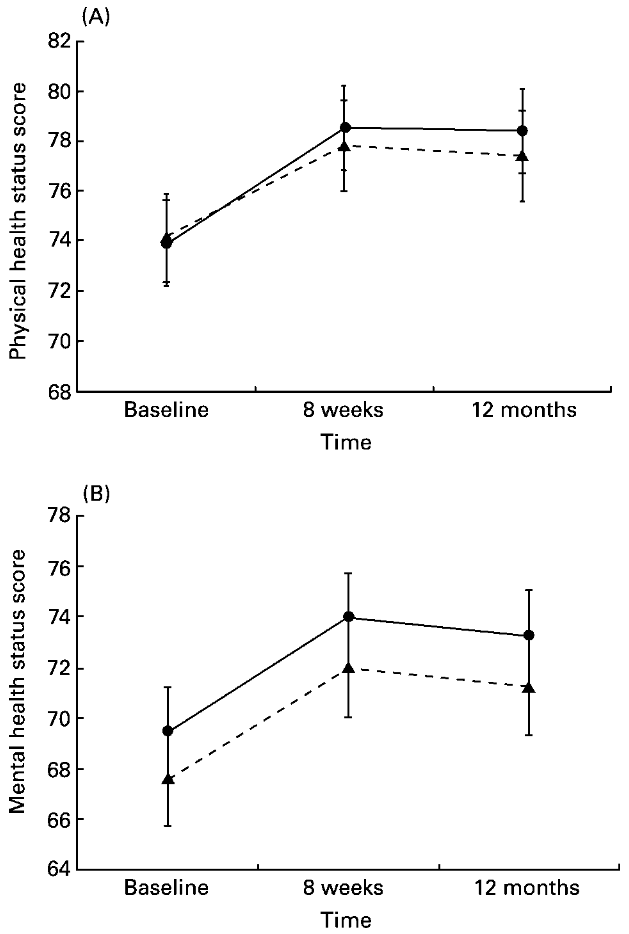

Fig. 1. Mean ratings on the physical (A) and mental (B) health status summary scales at baseline, 8 weeks and 12 months in the behavioural (–) and nutritional education (--) counselling conditions. All values are adjusted for gender, age, ethnicity, income, smoking and BMI. For details of subjects and procedures, see Table 1 and p. 178. Values are means with their standard errors shown by vertical bars.

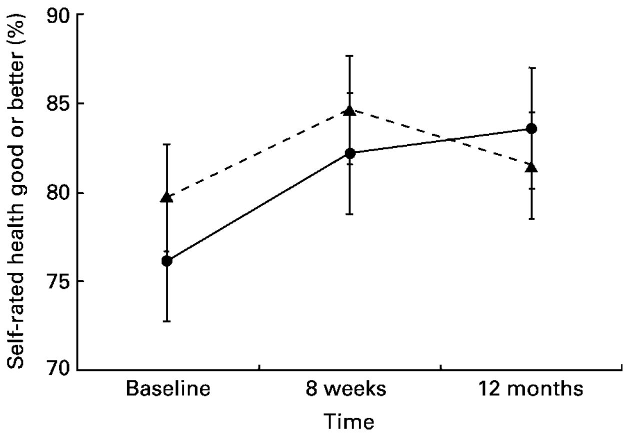

Fig. 2. Proportion of participants rating their health as good, very good or excellent at baseline, 8 weeks and 12 months in the behavioural (–) and nutritional education (--) counselling groups. All values are adjusted for gender, age, ethnicity, income, smoking and BMI. For details of subjects and procedures, see Table 1 and p. 178. Values are means with their standard errors shown by vertical bars.

The change in physical health status summary scores between baseline and 8 weeks was positively associated with change in fruit and vegetable consumption independently of covariates (B 0·80 (95 % CI 0·11, 1·50), $P<0·05$). The effect remained significant after additional control for fruit and vegetable consumption at baseline, so was not due to individuals with high initial intake showing larger changes in consumption and improvements in physical health status. Change in fruit and vegetable consumption remained associated with changes in physical health status over 12 months (B 1·17 (95 % CI 0·37, 2·02), $P<0·01$). Thus, individuals who reported greater increases in fruit and vegetable consumption also showed greater improvements in physical health status over the study period.

There was no significant association between changes in mental health status summary scores and fruit and vegetable consumption. In the case of self-rated health, effects at 8 weeks were not significant. However, the likelihood of showing an improvement from fair or poor to good health between baseline and 12 months was related to increases in fruit and vegetable consumption. The odds ratio adjusted for age, gender, ethnicity, income, smoking and BMI of reporting an improvement in self-rated health was 1·35 (95 % CI 1·08, 1·69; $P<0·01$) per unit increase in number of daily servings of fruits and vegetables. This effect remained significant after controlling for baseline fruit and vegetable intake.

Plasma vitamins and quality of life

The associations between baseline quality of life measures and baseline plasma vitamin E were not significant. But the change in vitamin E concentration between baseline and 12 months was positively related to changes in physical health status summary scores independently of age, gender, ethnicity, income, smoking, BMI and use of vitamin supplements at either time point (B 0·15 (95 % CI 0·01, 0·30), $P<0·05$). Similarly, the odds of an improvement in self-rated health were associated with increased vitamin E over 12 months (odds ratio 1·05 (95 % CI 1·01, 1·09), $P<0·01$). Changes in vitamin E between baseline and 8 weeks were related to the improvement in self-rated health over this time period as well (odds ratio 1·04 (95 % CI 1·00, 1·08), $P<0·05$), but not with the change in physical health status. We did not observe any associations between vitamin E and mental health status.

We found that the likelihood of good or better self-rated health was positively associated with baseline vitamin C, independently of covariates (odds ratio 1·02 (95 % CI 1·01, 1·03), $P<0·005$). Plasma vitamin C concentration at baseline was not related to physical or mental health status ratings. However, there was a positive association between changes in plasma vitamin C over 8 weeks and improvements in physical health status summary ratings independently of covariates (B 0·97 (95 % CI 0·41, 0·15), $P<0·001$). Thus, participants who showed larger increases in vitamin C concentration also reported greater improvements in physical health status. This association did not persist at 12 months, and no associations of vitamin C with changes in mental health status summary scores or self-rated health were identified.

Analyses were also carried out relating quality of life measures with β-carotene, but no significant associations were present.

Discussion

The present study was carried out in a primary-care centre in a low-income neighbourhood. One-third of participants were on very low incomes and in receipt of welfare benefits, while another one-third did not receive benefits, but were below our threshold for low income. Analyses not described here indicate that the interventions were equally effective when higher income participants were excluded (Steptoe *et al.* 2003*a*). Ethnic minority adults are often under-represented in research studies in the UK, but the 28·4 % of participants being black or Asian compares favourably with the estimated 22 % of non-white residents of the London borough in which the present study was carried out, according to the 2001 National Census. The fruit and vegetable intake of 3·64 portions per d at baseline is comparable with the average of 3·58 reported in the UK 1999 National Food Survey (Ministry of Agriculture, Fisheries & Food, 2000), although slightly greater than estimates in the 2000–2001 National Diet and Nutrition Survey (Henderson *et al.* 2002). Baseline levels of plasma vitamin C, vitamin E and β-carotene were comparable with those reported in other UK studies (Armstrong *et al.* 1997). The proportion of individuals taking vitamin supplements was similar to that described in the Health Survey for England (Erens & Primatesta, 1999).

Physical health status, mental health status and self-rated health all improved over the course of the study (Figs 1 and 2). These analyses were carried out on an intention to treat basis, so favourable responses were not due to the selective effects of only including data from subjects who successfully completed the trial. The changes took place during the intensive phase of the interventions (between baseline and 8 weeks), with little further change over the subsequent 10 months. We limited analyses to physical health and mental health summary scales rather than analysing all eight domains of the SF-36 separately, in order to reduce the number of analyses and risks of type I error. The quality of life responses cannot be attributed to reductions in body weight, since no significant changes were observed.

Few beneficial effects on quality of life have been reported in other dietary intervention studies. For example, the SF-36 was completed before and after 8 weeks of intervention in eighty-three participants in the Dietary Approaches to Stop Hypertension (DASH) trial (Plaisted *et al.* 1999). Few changes were observed in any of the quality of life domains, except that vitality increased in all three conditions (control, fruit and vegetable, and combination diets), body pain improved in the combination diet condition, and ratings of change in health improved in the two intervention conditions, but not the control conditions. Corle *et al.* (2001) included an amalgam of items from the SF-36 and the general well-being scale to assess quality of life in the Polyp Prevention Trial. No changes or differences between groups were observed, despite differences in fat and fibre intake and in fruit and vegetable consumption between the dietary intervention and control groups. In a study of women with type 2 diabetes, a comprehensive lifestyle management intervention involving a Mediterranean diet, stress management, physical activity, group support and smoking cessation produced greater improvements in glucose metabolism, BMI and plasma fatty acid concentrations than in control subjects over 6 months (Toobert *et al.* 2003). There were, however, no differences and no changes in physical or mental health assessed with the SF-12.

One explanation for the greater effects in the present study is that participants began with relatively poor health status (Table 1). Scores in all eight domains of the SF-36 were lower than in population surveys in the UK. This is likely to be due to the low socio-economic status of participants, since it is known that self-rated health and health-related quality of life are poorer in lower status groups (Jenkinson *et al.* 1993). By contrast, three scales of the SF-36 (physical, emotional and social role functioning) were near maximum in all participants in the DASH sub-study, so little further improvement was possible (Plaisted *et al.* 1999).

Both counselling conditions stimulated increases in reported fruit and vegetable consumption over the 12-month follow-up period, accompanied by increases in plasma vitamin E and β-carotene. The changes in fruit and vegetable intake and β-carotene were greater with behavioural than nutritional education counselling, from which we conclude that the provision of personalised advice based on behavioural principles supplemented the effects of nutritional education alone. The counselling was carried out by research nurses rather than by dietitians for two reasons. First, the research nurses also conducted physical assessments, including blood sampling and urinary measurement. Second, we anticipated that these methods might be most readily applied in primary care by practice nurses. It is interesting that despite the greater response from the behavioural counselling group in terms of reported consumption and plasma β-carotene, there was no difference between conditions in the changes in physical health status and quality of life. This indicates that the improvement in quality of life was not linked with the specific procedures used in one condition or another, but may have been a response to changes in diet.

This argument is supported by the second notable set of findings, concerning the relationships between fruit and vegetable intake and quality of life measures. The observation that consumption at baseline was associated with physical and mental health status is not unexpected, given the presumed health benefits of a diet rich in fruits and vegetables. More interesting is the observation that changes in fruit and vegetable consumption were associated with improvements in physical health status and self-rated health. The physical health status effects were significant at 8 weeks and 12 months, while the self-rated health effect emerged only at 12 months. These results indicate that individuals who reported greater increases in fruit and vegetable consumption also showed greater improvements in physical health and well-being. A Danish population study has previously demonstrated that poor self-rated health is more common among adults who do not consume good diets characterised by high fruit and vegetable intakes (Osler *et al.* 2001). Furthermore, over a 15-year follow-up period, mortality was associated both with poor self-rated health and poorer diets in the present study.

Scores on the mental health status measure improved in both groups during the trial, but were not associated with changes in fruit and vegetable consumption. This suggests that the mental health changes were non-specific responses to participation, rather than specific effects of dietary modification. It is possible that participants felt better for deciding to take part in the study, whether or not the outcome was favourable. Participation involved periodic support from research nurses together with encouragement of any appropriate behaviour changes, and these may have been sufficient to stimulate improvements in mental well-being.

Support for more specific effects of dietary change on physical health status and self-rated health was provided by analyses of plasma biomarkers. Increases in vitamin E at both 8 weeks and 12 months were associated with improved self-rated health, while changes in vitamin E at 12 months correlated with improved physical health status. Plasma vitamin C was associated with self-rated health at baseline. There was no significant change in plasma vitamin C on average, since some individuals showed increases while others showed decreases over the study period. The changes between baseline and 8 weeks correlated with the magnitude of improvements in physical health status. All these effects were independent of gender, age, ethnicity, income, smoking, BMI and the use of vitamin supplements, so may be direct consequences of changes in diet stimulating plasma vitamin responses.

Few controlled studies have related changes in vitamin intake with quality of life. The main interest has been in the impact of vitamins on cognitive function and mood (Martin *et al.* 2002). For example, Morris *et al.* (2002) found that cognitive decline over 3 years in a cohort of older adults was reduced in those with higher vitamin E intake. An inverse association between vitamin E and depression has been described in some studies (Shibata *et al.* 1999; Maes *et al.* 2000), but not in others once potential confounders had been taken into account (Tiemeier *et al.* 2002). Cross-sectional associations between vitamin C concentration and cognitive function have also been observed (Ortega *et al.* 1997), but longitudinal results have been inconsistent (Paleologos *et al.* 1998; Morris *et al.* 2002). A recent 12-month randomised controlled trial of vitamin and mineral supplements *v.* placebo in community-dwelling adults showed no significant changes or differences between groups in physical or mental health status assessed with the SF-12 (Barringer *et al.* 2003).

Our present results suggest that long-term changes in fruit and vegetable intake and plasma vitamin E concentration may have beneficial effects on physical health status and self-rated health. A review of the literature on self-rated health published until 1996 found that poor self-rated health predicted lower survival in twenty-three of twenty-seven studies even when known risk factors had been taken into account (Idler & Benyamini, 1997). This pattern has been replicated in more recent investigations (Kawada, 2003), and self-rated health also predicts future functional limitations (Idler *et al.* 2000). Physical functioning ratings predict adverse health outcomes as well. For example, Franks *et al.* (2003) analysed 5-year mortality data from 19 812 participants in the National Medical Expenditure Survey in the USA. Lower SF-20 scores on physical functioning, health perception and role functioning scales predicted reduced survival, with particularly strong effects among younger individuals. The changes in self-rated health and physical health status reported in this study may therefore be consequential in terms of broader health outcomes.

The present study was limited to residents in an ethnically mixed, low-income urban area, and may not be applicable to rural populations in other parts of the world. We have discussed issues of selection elsewhere (Steptoe *et al.* 2003*a*), but since results were only obtained from adults who agreed to participate in the trial, patterns might be different in the population at large. Only a summary measure of fruit and vegetable consumption was obtained, so detailed nutritional analyses could not be conducted and estimates of intake were not as precise as with more detailed instruments. Nonetheless, the results indicate that encouraging increases in fruit and vegetable intake in low-income populations does not have adverse effects on physical or mental health status, and may indeed lead to positive general health gains. The associations between individual differences in changes in consumption, plasma vitamin concentrations and quality of life suggest that modifying nutritional intake may have favourable effects on physical health status. Utilisation of these methods may help reduce socio-economic disparities in health behaviour and health.

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