British Journal of Nutrition (2016), **115**, 1760–1768
doi:10.1017/S0007114516000970

Increased intake of fruits and vegetables in overweight subjects: effects on body weight, body composition, metabolic risk factors and dietary intake

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(Submitted 15 October 2015 – Final revision received 12 February 2016 – Accepted 16 February 2016 – First published online 21 March 2016)

Abstract

A diet rich in fruits and vegetables has been associated with several health benefits. However, the effects on body weight (BW) and metabolic markers are not fully known. The present study investigated the effects of increased intake of fruits and vegetables in overweight and obese men and women on dietary habits, anthropometry and metabolic control. In a 16-week controlled intervention, thirty-four men and thirty-four women aged 35–65 years (BMI >27 kg/m^2) were randomised to an intervention (IN) or a reference (RG) group. All participants received general dietary advice, and subjects in the IN group received fruits and vegetables for free, of which ≥500 g had to be eaten daily. BW, waist circumference (WC), sagittal abdominal diameter (SAD), plasma insulin, blood glucose, glycated Hb (HbA1c), serum lipids, blood pressure, plasminogen activator inhibitor-1 activity, urinary isoprostane (iso-8-PGF 2α) and serum carotenoids were measured. Diet was assessed using 3-d weighed food records. In all, thirty subjects in the IN group and thirty-two in the RG group completed the intervention. Intake of fruits and vegetables doubled in the IN group, whereas intake of fruits increased in the RG group. Serum α- and β-carotene concentrations and intakes of folate and vitamin C increased significantly in the IN group. Energy intake, BW, WC and SAD decreased significantly in both groups. Supine systolic blood pressure decreased significantly in the IN group, with no between-group differences. No significant changes were observed for other metabolic markers. Provision of fruits and vegetables led to substantially increased intakes, with subsequent favourable changes in anthropometry and insulin levels, which tended to be more pronounced in the IN group. The observed improvements may, in combination with improved nutritional markers, have health benefits in the long term.

Key words: Fruits: Vegetables: Body weight: Food intakes: Metabolic markers

During the past few decades, there has been an increased prevalence of overweight and obesity and type 2 diabetes[1] in most parts of the world. Overweight and obesity increase the risk for type 2 diabetes, CHD and some cancers[2–4]. Efforts made to decrease the prevalence of dietary-related diseases include nutrition- and food-based recommendations issued by organisations and authorities in different countries. These include the Nordic Nutrition Recommendations[4,5] and recommendations on fat and fatty acids and carbohydrates issued by the Food and Agriculture Organization/WHO[6,7].

Fruits and vegetables are good sources of dietary fibre, vitamins and minerals and have a low energy density. A diet rich in fruits and vegetables has in some intervention studies been associated with favourable effects on metabolic risk factors including serum lipids, blood pressure (BP)[8–12] and body weight (BW)[13–15], although a lack of impact has also been reported[16,17]. Results from prospective cohort studies show inverse associations between fruit and vegetable intakes and stroke[18], CVD[19], total mortality[19,20] and some cancers[21–24]. Possible mechanisms/mediators for the favourable effect of fruits and vegetables include reduced dietary energy density, modulation of blood lipid and glucose response and BW by dietary fibre, as well as replacement of less-favourable foods[4,25]. Evidence for mechanisms involving antioxidants is, however, limited[4].

The impact of including an ample amount of fruits and vegetables to the diet on the overall food intake and subsequent effects on BW and metabolic risk factors is, however, not yet fully known. The Swedish food-based guidelines include advice to eat at least 500 g of fruits and vegetables per day, corresponding to about five portions a day[26]. Results from Swedish dietary surveys in adults show that mean intakes are well below the target of 500 g/d[27,28].

The overall objective of the present study was to investigate the effects of an increased intake of fruits and vegetables on BW, body composition and metabolic markers among overweight and obese men and women. The secondary aim was to study any influence on overall dietary habits.

All study subjects gave their informed consent for participation, and the study was approved by the Ethics Committee of Uppsala University (Dnr 00-035).

Abbreviations: BP, blood pressure; BW, body weight; E%, percentage of energy; HbA1c, glycated Hb; IN, intervention; RG, reference; SAD, sagittal abdominal diameter.

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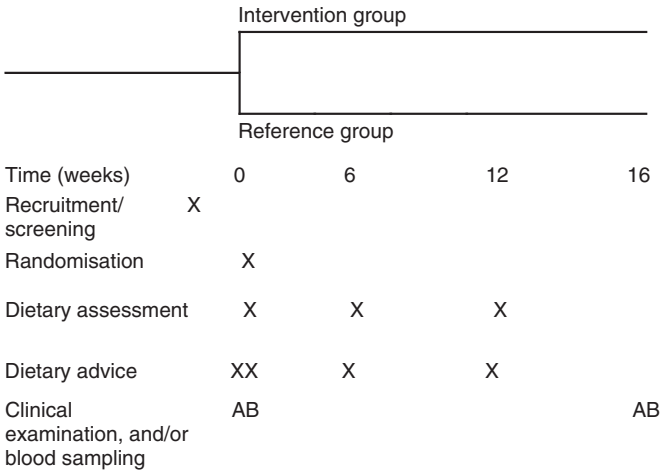

Fig. 1. Study design. Overview of timing of anthropometrical and clinical measurements and dietary assessment. X, indicates instances; A, blood pressure, body weight, waist circumference, sagittal abdominal diameter, fasting blood samples for the analysis of plasma insulin, blood glucose, glycated Hb (HbA1c), serum lipids (lipoproteins and apo), fatty acid composition of the serum phospholipids, fibrinolytic capacity (plasminogen activator inhibitor-1 activity), levels of antioxidative vitamins in plasma, lipid peroxidation (malondialdehyde) and 24-h collection of urine for the analysis of isoprostanes; B, body weight and blood samples for the analysis of TAG and cholesterol in serum, blood glucose and HbA1c.

Methods

Subjects

Subjects were recruited via advertising in the local Uppsala newspaper. Subjects aged 35–65 years who were overweight (BMI >27 kg/m^2) were invited to participate. In total, 375 women and seventy-seven men responded, and 320 women and seventy-three men fulfilled the requirements for age, weight and height. All men and 100 women, selected at random, were asked to respond to an initial questionnaire regarding state of health, use of drugs and health foods, food allergies and intolerances. In all, ninety-five women and fifty-five men met the inclusion criteria for age and BMI and were apparently healthy. All men and sixty-five randomly selected women were invited to a health and laboratory screening in order to exclude subjects with thyroid disease, kidney or liver damage, undiagnosed diabetes or high blood lipid levels. Of the screened subjects, thirty-four women and thirty-four men were included in the study.

Dietary intervention

Subjects were randomised into either an intervention (IN) or a reference (RG) group. Before randomisation, all participants received dietary advice from an experienced dietitian in line with the nutrition recommendations[5]. Dietary advice was given twice in groups of ten persons. The dietary advice given aimed at reducing total fat intake, decreasing the proportion of SFA, increasing the proportion of unsaturated fats, especially MUFA, increasing the intake of fish, increasing the intake of dietary fibre and increasing the intake of vegetables, roots, fruits and berries. The dietary advice given was food based, and participants were recommended to choose products labelled with the keyhole symbol[29] and to use the plate model for meal planning[30]. Dietary advice was also given to both groups in connection with the dietary assessment during weeks 6 and 12. The participants were instructed not to change their physical activity during the study period.

Participants in the IN group received fruits and vegetables for free throughout the entire study period, and at least 500 g had to be eaten daily. All products were collected once a week at the outpatient clinic. Participants in the IN group were offered to receive the same amount of vegetables and fruits for one additional family member. All fruits and vegetables were given in portion sizes of approximately 100 g. Recipes and instructions on how to prepare frozen vegetables for consumption were given to the participants as well as recipe folders. If the intake was <500 g/d, the subjects were encouraged to increase their intake. The different fruits given to the IN group were apples, pears, kiwi fruit, bananas and oranges/clementines. The fresh vegetables provided were white cabbage, carrots, tomatoes, pepper, onions, leek and Chinese cabbage. The deep-frozen varieties were string beans (haricots verts), broccoli, green peas, sweet maize and three different varieties of mixed roots and vegetables. Fig. 1 shows the study design.

Anthropometric and clinical measurements

At baseline and at the end of the study, the subjects went through a clinical examination with measurements of BP, BW, waist circumference (WC) and sagittal abdominal diameter (SAD). Fasting blood samples were collected for the analysis of plasma insulin, blood glucose, glycated Hb (HbA1c), serum lipids, lipoproteins and apo, fatty acid composition of serum phospholipids, fibrinolytic capacity, levels of antioxidative vitamins in plasma and lipid peroxidation; 24-h urine samples were collected for the analysis of isoprostanes. In connection with the dietary assessments at 6 and 12 weeks, BW was measured and blood samples were collected for the analyses of TAG and cholesterol in serum as well as blood glucose and HbA1c.

Height was measured without shoes to the nearest 0·5 cm and BW was measured to the nearest 0·1 kg without shoes in light

indoor clothing. BMI was calculated as the BW (kg) divided by the height squared (m^2). WC was measured midway between the lowest rib and the iliac crest. SAD (antero–posterior) was measured[31] in a recumbent position with the hips flexed.

BP was measured in the right arm with the subjects in the supine position after a 5-min rest period. Systolic BP (SBP) and diastolic BP (DBP) were defined as Korotkoff phases 1 and 5, respectively.

Blood samples were drawn from an antecubital vein, and all serum and plasma samples were stored at −70°C until analysed, if not analysed directly. All fasting blood samples were collected after a 12-h overnight fast.

Blood glucose concentrations were determined by the glucose oxidase method. HbA1c was measured by fast-performance liquid chromatography assay. Plasma insulin was measured by enzyme immunoassay using an ELISA-kit (Mercodia AB).

TAG and cholesterol concentrations were measured enzymatically in serum and in the isolated lipoprotein fractions using a Monarch apparatus (Instrumentation Laboratories). The concentrations of serum apo A-1 and B were determined by an immunochemical assay (Orion Diagnostica). HDL-cholesterol was separated by precipitation with magnesium chloride/phosphotungstate[32]. LDL-cholesterol was calculated using Friedewald's formula: LDL-cholesterol = serum cholesterol–HDL-cholesterol–(0·45 × serum TAG).

Plasminogen activator inhibitor-1 activity (PAI-1 activity) in plasma was measured using Spectrolyse/pL kits from Biopool AB.

Serum α– and γ-tocopherol concentrations were determined using HPLC with fluorescence detection[33] and were adjusted relative to serum lipid concentrations as suggested by Thurnham *et al.*[34].

Serum carotenoids (α-, β-), lutein and lycopene were determined by HPLC as described by Rytter *et al.*[35], and were used mainly as biomarkers of fruit and vegetable intake.

Plasma malondialdehyde (MDA) concentration was measured by HPLC[36], and urine 8-iso-PGF 2α was analysed by a specific and validated RIA developed by Basu[37]. The levels of 8-iso-PGF 2α in urine were adjusted for creatinine concentrations.

Dietary assessments

At baseline, participants completed a 3-d weighed dietary record before receiving dietary advice, which included 2 consecutive weekdays and 1 d during the weekend. The food intake was also recorded after 6 weeks and after 12 weeks, respectively. The food record was completed during the same weekdays and weekend days on all three occasions. Subjects received oral and written instructions from a dietitian, including details on food description. The food items were weighed to the nearest gram on an electronic kitchen scale (Soehnle) with a precision of 0·1 g.

Follow-up

After 1 year of completion of the study, participants in both groups were invited for a follow-up, which included the same measurements and blood sampling as at baseline and study completion. In addition, another 3-d weighed food record was obtained.

Dietary analysis

Energy and nutrient intakes were calculated using commercial dietary analysis software (MAT, version 4.03; Rudans lättdata), which includes the Swedish National Food Agency's food composition database (version 04.1.1). The nutrient composition of dishes was calculated using subject-specific recipes according to the food records or standard recipes. For a few food products, values were obtained from the manufacturer or calculated based on similar foods in the food composition database.

Statistical analyses

The statistical analysis was performed using SAS for Windows, version 8.0 (SAS Institute), and Minitab for Windows, version 15 (Minitab Inc.), using the general linear model (GLM) for differences between groups and pair-wise *t* tests for changes within groups. *P* values <0·05 were considered significant. Data on significances are presented for between-group differences at baseline as well for within-group and between-group changes during the intervention. Power calculations were performed for BMI. In all, thirty participants in each group were estimated to allow detection of a difference in BMI of 2 units with 80 % power at $P < 0{\cdot}05$.

Results

In total, sixty-two of the sixty-eight subjects (thirty in the IN and thirty-two in the RG group) completed the 16-week intervention, corresponding to 91 % participation. Baseline data for these are given in Table 1. There were no differences between dropouts and study participants. In total, forty-nine subjects (twenty-four in the IN and twenty-five in the RG group) participated in the follow-up 1 year after the intervention period was completed.

Anthropometry

BW, BMI, WC and SAD did not differ significantly between the two groups at baseline (Table 1). At the end of the study period, BW, WC and SAD had decreased significantly in both groups, but without any significant between-group differences in change during the intervention. BMI decreased significantly from baseline in both groups.

Metabolic and clinical variables

No significant changes were seen for major serum lipids or apo in either group during the intervention period (Table 1).

At baseline, insulin levels were 70 % higher (NS) in the RG than in the IN group (Table 1). At the end of the intervention period, levels had decreased in both groups, being statistically significant in the IN group ($P < 0{\cdot}05$), without significant between-group differences. No significant changes were seen for plasma glucose. Minor, but significant ($P < 0{\cdot}05$), increases in HbA1c concentrations were seen in both groups.

Table 1. Anthropometric, clinical variables, serum carotenoids and tocopherols at baseline and at end of the study period for subjects who participated at baseline and at the end of the intervention (IN) period
(Mean values and standard deviations)

	IN (*n* 30)				RG (*n* 32)				
	Baseline†		16 weeks‡		Baseline†		16 weeks‡		
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Between-group change (*P*)§
Weight (kg)	94·4	7·3	91·3***	7·5	95·3	13·4	93·5**	14·3	NS
Women	91·9	7·1	88·7	6·6	86·6	9·0	84·5	9·1	
Men	96·8	6·9	94·0	7·5	104·0	11·2	102·6	12·7	
BMI (kg/m^2)	31·2	2·7	30·1***	2·6	31·6	2·7	31·0**	3·2	NS
Women	32·5	2·5	31·3	1·9	31·2	2·5	30·4	2·7	
Men	29·8	2·3	29·0	2·7	32·0	2·9	31·6	3·5	
Waist circumference (cm)	105·2	5·5	101·1***	6·4	105·8	7·6	101·9***	9·3	NS
Women	105·6	4·9	103·0	6·4	102·1	5·9	97·3	7·4	
Men	104·7	6·1	100·0	6·2	109·5	7·3	106·8	8·7	
Sagittal diameter (cm)	26·7	1·4	25·3***	1·4	26·7	2·4	25·7***	2·8	NS
Total cholesterol (mmol/l)	5·27	0·97	5·29	0·99	5·19	1·09	5·18	1·07	NS
LDL-cholesterol (mmol/l)	3·36	0·75	3·41	0·81	3·37	0·95	3·33	0·97	NS
HDL-cholesterol (mmol/l)	1·18	0·25	1·23	0·29	1·22	0·33	1·25	0·30	NS
LDL:HDL ratio	2·95	0·87	2·88	0·82	2·88	0·94	2·78	0·82	NS
Apo-A1 (g/l)	1·33	0·19	1·33	0·21	1·35	0·21	1·34	0·18	NS
Apo-B (g/l)	1·05***	0·18	1·01	0·18	0·98	0·17	0·96	0·17	NS
Serum TAG (mmol/l)	1·57	1·01	1·39	0·59	1·37	0·51	1·31	0·63	NS
HDL-TAG (mmol/l)	0·07	0·03	0·13*	0·02	0·09	0·08	0·09	0·06	NS
HbA1c (%)	4·24*	0·31	4·30*	0·30	4·29	0·39	4·37**	0·40	NS
Insulin (mU/l)	8·31	4·36	6·89*	3·51	14·2	23·8	10·3	8·4	NS
Plasma glucose (mmol/l)	5·27	0·55	5·23	0·63	5·18	0·90	5·24	0·81	NS
DBP, supine (mmHg)	80·1	8·0	79·0	7·1	79·6	6·4	79·2	6·1	NS
SBP, supine (mmHg)	130·2**	19·1	124·1*	12·5	123·6	13·4	121·6	10·9	NS
8-iso-PGF 2*α* (nmol/mmol creatine)	0·29	0·08	0·31	0·07	0·32	0·14	0·30	0·13	<0·05
MDA (μmol/l)	0·50	0·10	0·57***	0·11	0·53	0·12	0·54	0·11	<0·05
PAI-1 (U/ml)	28·0	23·0	20·9	15·7	20·0	16·5	20·6	16·3	NS
α-Carotene (mg/l)	0·10	0·12	0·17***	0·12	0·07	0·04	0·08*	0·06	<0·001
β-Carotene (mg/l)	0·30	0·30	0·47***	0·34	0·24	0·14	0·26	0·17	<0·001
Lutein (mg/l)	0·14	0·07	0·16***	0·06	0·13	0·05	0·14	0·08	<0·05
Lycopene (mg/l)	0·23	0·07	0·23	0·09	0·21	0·08	0·21	0·07	NS
α-Tocopherol (mmol/l)	1·54	0·31	1·57	0·18	1·60	0·19	1·63	0·20	NS
γ-Tocopherol (mmol/l)	0·10	0·04	0·09	0·02	0·11	0·05	0·10	0·04	NS

RG, reference; HbA1c, glycated Hb; DBP, diastolic blood pressure; SBP, systolic blood pressure; MDA, plasma malondialdehyde; PAI-1, plasminogen activator inhibitor-1 activity.
† Statistically significant differences between IN and RG at baseline: * $P<0·05$, ** $P<0·01$.
‡ Statistically significant differences between baseline and week 16: * $P<0·05$, ** $P<0·01$, *** $P<0·001$.
§ Between-group change indicates differences between changes from baseline to 16 weeks within the two groups during the intervention.

Supine SBP decreased in the IN group by 6 mmHg ($P<0·05$) and in the RG group by 2 mmHg (NS) at the end of the intervention period without any between-group differences. Supine DBP did not change in either group.

Urinary isoprostane (iso-8-PGF 2*α*) levels did not change. MDA levels increased in the IN group ($P<0·05$) compared with the RG group. PAI-1 levels did not change significantly in either group.

At baseline, *α*- and *β*-carotene levels were higher in the IN group than in the RG group (Table 1). At the end of the intervention, levels had increased in both groups, although the increase was more profound in the IN group ($P<0·001$). Lutein levels were also increased in the IN group ($P<0·05$) compared with the RG group. No significant changes in *α*- and *γ*-tocopherol levels were seen in either group during the study period.

1-Year follow-up. Among subjects who participated in the follow-up examination 1 year after the end of the intervention period, BW ($P<0·01$) and BMI ($P<0·01$) had increased in both groups, although lower compared with baseline, and weight reduction was significantly larger in the IN group than in the RG group ($P<0·05$) and BMI was lower as well ($P<0·05$). SAD had decreased further by about 1 cm in both groups ($P<0·001$), and the change from baseline was larger in the IN group than in the RG group ($P<0·05$). No significant changes in serum lipids were seen but apo-1 levels had increased in both groups ($P<0·05$). HbA1c levels were significantly higher in both groups ($P<0·001$), with no differences in plasma glucose levels. Insulin levels had increased in the IN group, but were still lower compared with the RG group. No changes were seen for PAI-1 or SBP in either group, whereas DBP had decreased in the RG group ($P<0·05$), with no change in the IN group (data not shown).

Food and nutrient intake

There were no significant differences between the IN and RG groups with respect to the intake of fruits and vegetables at the

Table 2. Intake of selected foods (g/d) in the intervention (IN) and the reference (RG) group at baseline and during the intervention period (Mean values and standard deviations)

	Baseline†		6 weeks		12 weeks‡			
	Mean	SD	Mean	SD	Mean	SD	Mean change	Between-group change (*P*)§
Edible fats								
IN	19	15	23	29	14	15	−1	
RG	20	17	12	11	15	16	−6	NS
Cheese								
IN	31	22	25	18	22*	17	−7	
RG	30	22	22	17	27	25	−6	NS
Milk								
IN	330	194	238	180	248*	192	−83	
RG	335	312	291	250	289	228	−45	NS
Bread								
IN	104	52	96	58	91	66	−10	
RG	109	39	115	57	115	54	5	NS
Potatoes								
IN	141	76	93	87	89**	67	−50	
RG	131	95	126	82	115	84	−10	NS
Root vegetables								
IN	31	49	66	49	62*	60	33	
RG	22	47	31	60	27	45	7	NS
Vegetables and dishes								
IN	207	163	490	198	436***	156	256	
RG	166	118	185	126	202	137	27	<0·001
Fruits and berries								
IN	202**	149	418	132	394***	161	204	
RG	113	97	221	166	210***	140	102	<0·05
Fruit juice								
IN	78	108	99	133	41	63	−8	
RG	58	94	51	87	61	101	−2	NS
Nuts, seeds								
IN	4·1	14·5	0·5	1·7	2·9	9·3		
RG	0·6	3·5	1·9	9·4	1·9	5·8		NS
Meat including dishes								
IN	120	80	104	71	110	84		
RG	146	87	123	68	131	97		NS
Sausages including dishes								
IN	27	28	26	41	26	49		
RG	36	45	30	44	21	27		NS
Fish including dishes								
IN	61	56	52	45	52	53		
RG	31	39	48	50	46	62		NS
Sweet bakery products								
IN	56	46	27	28	35*	39	−25	
RG	48	66	19	25	25*	26	−26	NS
Ice-cream								
IN	23	32	2	7	8	14	−18*	
RG	20	44	8	18	8	18	−12	NS
Soft drinks								
IN	112*	226	61	137	57	83	−53	
RG	63	121	63	131	38	101	−13	NS

† Statistically significant differences between IN and RG at baseline: * $P<0·05$, ** $P<0·01$.
‡ Statistically significant differences between baseline and week 12: * $P<0·05$, ** $P<0·01$, *** $P<0·001$.
§ Between-group change indicates differences between changes from baseline to 12 weeks within the two groups during the intervention.

study start (Table 2). After 6 weeks, the intake of both fruits and vegetables had increased about 2-fold in the IN group (Fig. 2), which was largely maintained at week 12 ($P<0·001$). The intake of fruits also increased in the RG group ($P<0·01$), but was less than that in the IN group. The intake of fruit juices was lower ($P<0·05$) at week 12 in the IN group, with no changes in the RG group. Changes in the intakes of other food groups during the study period were relatively limited (Table 2).

Reported energy intake decreased significantly during the study period in both groups, with no between-group differences. The percentage of energy (E%) from total fat, SFA and MUFA decreased at week 12, with no between-group differences (Table 3). E% from carbohydrates and monosaccharides increased significantly in both groups, whereas E% from sucrose tended to decrease significantly only in the RG group. No significant changes were seen for the proportion of major fatty acids in the diet (data not shown).

During the study period, the intake of β-carotene, folate, vitamin C and dietary fibre increased significantly in the IN compared with the RG group (Table 3). Changes for other micronutrients were limited.

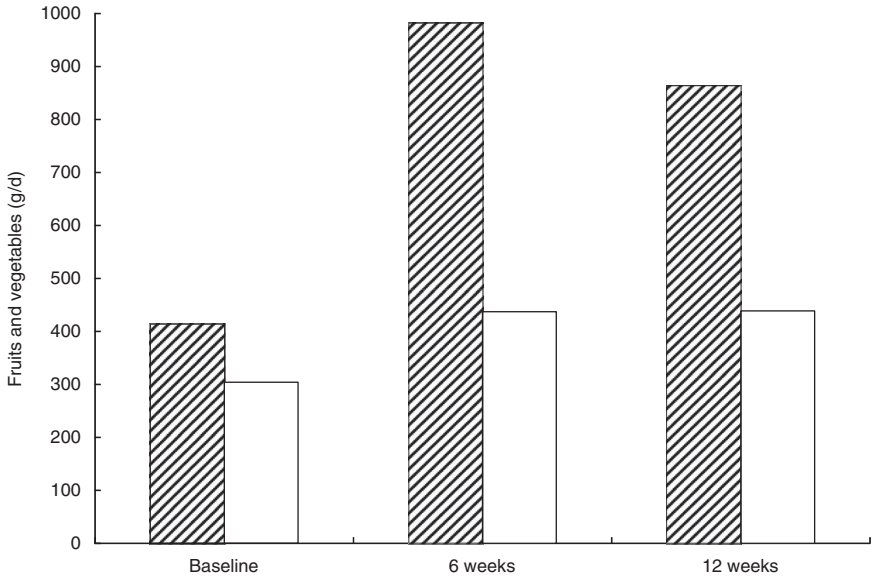

Fig. 2. Mean total intake of fruits and vegetables (excluding fruit juice) at baseline and during the study period. ▨, Intervention; □, usual care.

1-Year follow-up. At follow-up, intake of fruits was significantly higher in the IN ($P<0·05$) and in the RG group ($P<0·01$) compared with baseline. Reported energy intakes were significantly lower compared with baseline in both groups ($P<0·05$), whereas E% for macronutrients and intakes of most micronutrients were not significantly different from baseline in either group (data not shown).

Discussion

The main aim of the present study was to investigate the effects of an increased intake of fruits and vegetables on several anthropometric and metabolic markers associated with risk of CVD and type 2 diabetes, but also to study effects on other dietary changes. An intake of at least 500 g/d was the target, and an ample amount of fruits and vegetables was provided to the subjects in the IN group together with general dietary advice and recipes.

Dietary changes

In the IN group, the total intake of fruits and vegetables (excluding fruit juice) increased about 2-fold during the intervention (Fig. 2). This shows that the intervention was successful and that most subjects ate the provided amounts of fruits and vegetables (≥500 g/d). The fact that the RG group increased the intake of fruits, but not vegetables, during the study period could be interpreted as changes in the intake of fruits are easier to achieve than changes in the intake of vegetables. There was also a trend for decreased intake of sugar-containing foods, indicating an influence of the dietary advice.

Reported energy intake decreased in both groups during the study period and the dietary composition changed (Table 3). Some under-reporting was evident, but changes in reported energy intakes were similar in both groups. E% from fat decreased, whereas the intake of monosaccharides (both in grams and as E%) increased significantly in the IN group, which can be attributed to the increased intake of fruits and vegetables. Intake of sucrose (as E%) decreased in the RG group, with no significant changes in the IN group – the latter reflecting the increased intake of fruits. Pronounced increases in the intakes of β-carotene, folate, vitamin C and dietary fibre were seen in the IN group during the study, and plasma concentrations of α-and β-carotene also increased, thereby confirming the dietary data.

At the follow-up, 1 year after the completion of the intervention period, the total intake of fruits and vegetables was still higher compared with baseline, especially in the IN group. This indicates that the increased availability in the IN group during the study period had a longer-lasting influence on behaviour than general dietary advice.

Effects on anthropometry and clinical markers

At the end of the 16-week intervention period, favourable changes in certain anthropometric measures and markers of glucose metabolism were seen, and changes tended to be more pronounced in the IN group. Insulin levels decreased in both groups, significant for the IN group only ($P<0·05$). No significant between-group changes were seen for BP, major serum lipids and apo, or plasma glucose and HbA1c levels. Power calculations were carried out for differences in BMI. The relatively wide variation in initial BP reduced the power to detect significant differences in BP between groups during the intervention.

The results of the present study are in line with other interventional studies, which indicate favourable effects of increased intakes of fruits and vegetables on BW[11,13] and on some markers of the metabolic syndrome[10–12]. Other studies have, similar to our study, shown minor or no clear effects on serum lipids[11,17,38–40]. We found limited effects on BP, similar to two

Table 3. Average daily intake of energy, proximates, dietary fibre and some micronutrients in the intervention (IN) and reference (RG) groups (Mean values and standard deviations)

		Baseline†		6 weeks		12 weeks‡			
Nutrients	Group	Mean	SD	Mean	SD	Mean	SD	Mean change	Between-group change (*P*)§
Energy (kJ)	IN	9860	2150	8590	1860	8320**	2770	−1400	
	RG	9180	2870	7830	2420	7300***	1780	−1620	NS
Protein (E%)	IN	16·3	2·3	16·9	2·7	17·4*	2·9	0·8	
	RG	16·6	3·3	18·2	3·2	18·2*	2·7	1·6	NS
Fat (E%)	IN	30·8	5·9	27·7	7·2	25·6***	4·9	−4·2	
	RG	31·4	6·1	28·4	6·3	27·5*	5·6	−3·4	NS
SFA (E%)	IN	12·7	3·0	10·4	3·1	10·2***	2·4	−2·4	
	RG	12·8	2·7	11·4	2·6	10·9**	2·7	−1·7	NS
MUFA (E%)	IN	11·4	2·5	10·1	3·1	9·4**	2·3	−1·6	
	RG	12·0	2·7	10·4	2·5	10·4*	2·3	−1·6	NS
PUFA (E%)	IN	4·5	1·2	5·0	2·2	3·9	1·0	0·0	
	RG	4·7	1·7	4·5	2·0	4·7	2·6	0·1	NS
Carbohydrate (E%)	IN	50·1	7·3	53·5	7·3	54·2*	6·7	3·8	
	RG	48·9	7·4	51·9	7·5	52·6*	6·3	3·3	NS
Sucrose (E%)	IN	8·6	3·6	8·4	3·1	8·7	2·7	−0·0	
	RG	9·0	4·3	7·2	3·6	7·2*	3·3	−1·9	NS
Monosaccharides (E%)	IN	8·0	3·8	12·3	3·8	12·0	3·4	4·2	
	RG	6·3**	2·6	8·3	4·2	8·1**	3·4	1·9	<0·01
Alcohol (E%)	IN	2·9	4·3	2·0	2·8	2·9	6··5	−0·4	
	RG	3·2	5·1	1·7	2·1	1·8	2·6	−1·5	NS
Retinol (μg)	IN	783	453	764	1042	533**	394	−178	
	RG	930	1350	715	842	751	1020	−197	NS
β-Carotene (mg)	IN	2·90	3·21	9·12	5·34	7·88***	4·63	5·70	
	RG	2·32	2·71	3·74	4·26	3·37	3·18	1·23	<0·001
α-Tocopherol, mg	IN	9·6	2·1	11·2	4·0	9·5	3·1	0·7	
	RG	8·7	3·5	8·0	3·4	7·5	2·5	−0·9	<0·05
Folate (μg)	IN	312	92	516	230	438***	127	162	
	RG	284	80	306	102	295	92	16	<0·001
Vitamin C (mg)	IN	123	85	298	157	221***	72	134	
	RG	92	61	112	62	118	67	24	<0·001
K (g)	IN	4·00	0·96	4·54	1·31	4·38	1·11	0·44	
	RG	3·66	1·35	3·56	0·94	3·50	0·87	−0·13	NS
Na (g)	IN	3·48	0·74	3·25	1·25	3·05*	1·15	−0·35	
	RG	3·43	1·12	3·22	0·80	3·03*	0·81	−0·31	NS
Mg (mg)	IN	403	95	436	114	435	121	29	
	RG	354**	101	361	101	351	85	2	NS
Cholesterol (mg)	IN	372	97	276	144	263	136	−105	
	RG	373	186	297	131	316	157	−67	NS
Dietary fibre (g)	IN	23·7*	8·5	38·3	10·7	37·0***	12·8	13·6	
	RG	19·2	5·9	24·7	8·7	24·2***	7·8	5·2	<0·001

E%, percentage of energy.
† Statistically significant differences between IN and RG at baseline: * $P<0·05$, ** $P<0·01$.
‡ Statistically significant differences between baseline and week 12: * $P<0·05$, ** $P<0·01$, *** $P<0·001$.
§ Between-group change indicates differences between changes from baseline to 12 weeks within the two groups during the IN.

other studies[17,40]. In other studies, increased intake of fruits and vegetables resulted in lower BP compared with the control[9,11,41]. The somewhat diverging results in different studies may partly be due to differences in design, study populations, baseline diets, amounts and types of fruits and vegetables consumed during intervention and duration (see online Supplementary Table S1).

A few intervention studies have investigated the effects of increased intake of fruits and vegetables on glucose and insulin response and markers of inflammation. Flood *et al.*[12] randomised subjects with previous colorectal adenoma to advice on a low-fat, high-fibre and high fruit and vegetable diet or general dietary guidance. After 4 years, no differences were seen for serum concentrations of insulin, glucose, IGF-I (insulin-like growth factor-1) and IGFBP-3 (insulin-like growth factor-binding protein). In our study, insulin concentrations decreased in the IN group, whereas no consistent pattern was seen for glucose concentrations or markers of inflammation. No effects on insulin resistance were seen in one study after increased intakes from about 160 g/d up to <500 g/d during 16 weeks[16]. In a systematic review, including six prospective cohort studies, no consistent association with diabetes risk was found for fruit and vegetable intake[15,42]. However, an inverse association was found for intake of green leafy vegetables. In addition, biomarkers of fruit and vegetable intake were found to be inversely related to type 2 diabetes in a nested case–control study within the European Prospective Investigation into Cancer and Nutrition (EPIC) cohort 2015[43]. Dietary intake of carotenoids was also inversely related to type 2 diabetes in the Dutch cohort of the EPIC study[44].

A diet rich in fruits and vegetables has in cohort studies been associated with lower BP[45], and in other studies with long-term health benefits, for example, lower risk of some cancers

or colorectal adenomas[2,22,24,46,47], CVD[18,19] and total mortality[19,20]. Results from mainly epidemiological studies have shown some evidence for a relationship between fruit and vegetable intakes and BW[13,14,25].

The strengths of this study include controlled intervention with ample supply of fruits and vegetables in the IN group, resulting in high adherence. The dietary quality of the study groups was better compared with the general adult population already at the beginning of the study, including a higher intake of fruits and vegetables, which may have resulted in less pronounced differences in the study outcomes between the IN and RG group, especially as improvements in the diet was seen in the RG group as well.

Conclusions

Compared with subjects who received general dietary advice, provision of ample amounts of fruits and vegetables led to substantial increases in fruit and vegetable intake among overweight subjects. The increased intake was accompanied by favourable changes in BW and other anthropometric measures and insulin levels, and these changes tended to be more pronounced than in subjects given dietary advice only. These changes may, in combination with increased serum concentrations of carotenoids, and vitamin C and folate intakes, have health benefits in the long term with respect to, for example, risk of CVD, certain cancers and type 2 diabetes.

Acknowledgements

The authors thank Siv Tengblad for eminent analytical support and Professor Samar Basu for management of the isoprostane analysis.

The study was supported by a grant from the Swedish Council for Forestry and Agricultural Research. Additional funding was obtained from Uppsala county council; ICA Handlarna AB supported the study with all the fresh vegetables, roots, fruits and berries for the whole study period. Nestlé Sverige AB supported the study by providing all deep-frozen vegetables and vegetable mixes throughout the whole study period (Findus products).

The authors' contributions are as follows: A. J. had main responsibility for the study design and for conducting the study. B. K. and B. V. assisted in design and evaluation. W. B. had main responsibility for compilation and statistical analysis. All authors contributed to the writing of the manuscript.

The authors declare that there are no conflicts of interest.

Supplementary material

For supplementary material/s referred to in this article, please visit http://dx.doi.org/10.1017/S0007114516000970

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