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The effectiveness of long-term fibre supplementation on weight maintenance in weight-reduced women

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OBJECTIVE: To investigate whether fibre supplementation is effective in weight-reduced subjects for maintenance of weight-loss in the long-term.
DESIGN: Longitudinal, randomly assigned intervention study with supplementation of 20 g of water soluble fibre (guar gum) daily for 14 months after an energy-restricted period of two months (VLCD).
SUBJECTS: Thirty-one female, obese subjects (age: 41.4 ± 7.4 y; BMI 33.2 ± 3.7 kg/m^{-2}); 20 subjects were supplemented with fibre and 11 subjects served as the control group.
MEASUREMENTS: Body weight (BW), blood lipids and blood pressure, anthropometry, and eating behaviour were measured before the VLCD (0), after VLCD (2), and at 4, 10 and 16 months.
RESULTS: The fibre group with at least 80% compliance (group A) and the control group showed the same weight regain response after VLCD. The fibre consuming group with 50–80% compliance (group B) differed with respect to relapse. The rate and amount of BW regain was significantly higher for group B. After 14 months group B had returned to baseline levels, whereas group A and the control group showed a tendency to a lower BW than at baseline ($P = 0.09$). No effect of fibre supplementation was found on blood lipids, blood pressure and energy intake. Eating behaviour characteristics changed during the intervention and might explain differences in weight maintenance.
CONCLUSIONS: No effect of 14 months fibre supplementation was found on weight maintenance in weight-reduced subjects. Guar gum intake did not result in reduction of blood pressure or cholesterol, or in suppression of energy intake.

Keywords: weight-reduced subjects; fibre supplementation; guar gum; eating behaviour; weight maintenance

Introduction

Weight loss interventions have been shown to be successful but results in the long-term are disappointing.[1–3] Weight maintenance studies so far showed that successful weight maintainers exercised, were well motivated, managed stress well, used social support, and knew the type and quantity of food that was consumed.[4,5] Because weight maintenance is achieved when energy intake and energy expenditure are balanced, alteration of the type and quantity of food consumed seems to be the easiest way of changing energy balance. Studies with bulking agents like fibres were carried out to investigate whether supplementation of fibre resulted in decreased food intake. Fibres were found to be effective in increasing feelings of fullness[6–8] and had a satiating effect.[9,10] This could result in a decreased energy-intake. Since it is also known that obese, and especially severely obese, subjects consume less fibre than their lean counterparts, supplementation of dietary fibre might be effective in reducing energy intake and therefore result in weight loss or weight maintenance.[11,12]

In this present study a water soluble fibre, guar gum, was used to study the effect at weight maintenance. Guar gum, obtained from the endosperm of the Indian cluster bean *Cyamopsis tetragonolobus*, is a galactomannan, which in contact with water forms a highly viscous gel.[13] We used an enzymatically modified guar gum. This water soluble fibre hydrolysate has been reported to have the same effects as the native form.[14] It is reported that fibre has a major effect on blood pressure and cholesterol levels,[15] and also improves the insulinaemic response.[16] The improved insulinaemic response as a result of fibre supplementation could by itself be a useful physiological response to prevent obesity and weight gain.[15] We had previously found an effect of the guar gum supplement on energy intake and hunger and satiety feelings[17] in a short-term intervention study. The lowered energy intake found and increased satiety feelings reported, might be beneficial for weight maintenance in the long-term.[6,18,19]

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In this study the effect of long-term fibre supplementation (14 months) was studied in 31 weight-reduced females, with respect to body weight maintenance, cholesterol and blood pressure, while energy intake and eating behavior characteristics were taken into account.

Methods

Study design

Maintenance of body weight after two months of a very low calorie diet (VLCD; 2 MJ/d^{-1}) was studied for 14 months. The fibre intervention was studied in one group of subjects by supplementation with 20 g of water soluble fibre daily (guar gum), compared to one control group; randomization was executed after the VLCD period. Before (month 0) and after the VLCD period (month 2) measurements were carried out. During the weight maintenance phase these measurements were repeated at 4, 10 and 16 months. Written informed consent was obtained from each subject at the start of the study. The study was reviewed and approved by the Medical Ethical Committee of the Maastricht University.

Subjects and drop-out information

The very low calorie diet (VLCD) period was started with 48 female obese subjects. 41 subjects completed the VLCD-period. Seven females dropped out of the study during the VLCD period, because they were not able to follow the strict VLCD regime. Two subjects lost less than 5 kg of body weight (BW) during the VLCD and were excluded (set a priori as a measure of compliance to the VLCD ($n=39$). The subjects were randomly assigned to a fibre supplemented group ($n=25$) and a non-treated group ($n=14$). During the weight maintenance phase eight subjects dropped-out and a complete data set was obtained for 31 subjects. One subject was not able to come for the test at month 10, therefore she has been left out of the analysis. One subject became pregnant and another subject had a spinal cord operation. Five subjects stopped participation because of personal circumstances. Thus, the data presented in this study are based upon 31 female subjects (age 41.4 ± 7.4 y; height: 1.64 ± 0.06 m; BW 88.7 ± 10.4 kg). The 17 subjects that dropped-out of the study had similar baseline characteristics (age 36.7 ± 10.7 y; height 1.65 ± 0.06 m; BW 86.6 ± 10.5 kg).

Fibre supplementation

Subjects supplemented with fibre were asked to consume 10 g of guar gum fibre twice daily (20 g in total). The fibre supplement was an enzymatically modified guar gum (Benefiber, Sandoz Nutrition, Minneapolis, US), which has the same characteristics as the native form.[21] Subjects were asked to consume 10 g of fibre in the afternoon and 10 g in the evening. The fibre supplement was dissolved in 200 ml solution like water, coffee or orange juice to facilitate fibre intake. No placebo for this fibre supplement was available.

Measurements

Subjects came to the lab after an overnight fast at 8.00 am, by car or public transport to minimize physical activity at 0, 2, 4, 10 and 16 months.

Blood analysis

At all test days, blood samples were obtained (10 ml EDTA and 10 ml serum) from each subject. Blood plasma was mixed with EDTA to prevent clotting, and immediately centrifuged. Serum blood was centrifuged after one hour at room temperature. Blood samples were stored at -80°C until further analysis. Plasma glucose was determined by means of a hexokinase method (Cobas Bio, Roche Diagnostics, Hoffmann-La Roche, Basle, Switzerland). Plasma insulin was measured using a double antibody radioimmunoassay for human insulin (Kabi Pharmacia Diagnostics AB, Uppsala, Sweden). For determination of free fatty acids we used plasma (Cobas Fara, Wako, NEFA C, Wako Chemicals, Neuss, Germany). Free glycerol and total glycerol-concentrations were determined with a kit of Boehringer (Cobas Bio, Mannheim, Germany). Total cholesterol, LDL and HDL cholesterol, apo-a1, apo-b and Lp(a) were determined as described by Muls and coworkers.[20]

Anthropometry

Anthropometric data obtained at each test were: body weight (BW), height, body fat percentage and waist-hip ratio (WHR). The deuterium dilution technique was used for measurement of body composition in this study.[21] Subjects were asked to collect a urine sample in the evening just before drinking the deuterium enriched water solution. After consumption of this enriched water no more water and food was consumed. The next morning subjects came after an overnight fast to the lab for the measurement session. Ten hours after drinking the water solution another urine sample was collected. The degree of dilution of the deuterium isotope is a measure for total body water of the subject.[22]

Energy intake

The amount of food consumed during the 14 month study period was calculated with analysis of the completed food-intake diary. Subjects were asked to write down everything that was consumed (meals, drinks and snacks) at two normal week days and one weekend day at every time point of the study. The diaries were analysed with the Dutch food tables[23] and the accessory computer program.

Eating behavior

Eating behavior was analyzed with a Dutch translation of the Three Factor eating behavior questionnaire (TFEQ)[24] after each test day.[25] Cognitive restrained and unrestrained eating behavior (Factor 1), disinhibition (Factor 2) and the hunger factor (Factor 3) were scored. Body weight fluctuation was checked with the Herman and Polivy questionnaire.[26]

Compliance to fibre intake during the weight maintenance phase

The fibre supplemented subjects were asked to consume two sachets of 10 g of fibre daily. Actual fibre intake was checked by questionnaire when subjects were asked to report the amount of fibre consumed during a week and counting of returned sachets. Based upon this information two subgroups were classified. One group of subjects consumed more than 80% of the supplemented amount of fibre (group A; $n=10$) and group B consumed between 50–80% of the required amount of fibre ($n=10$). The data in this report is presented for three subgroups; group A and B, and the control group C ($n=11$).

Because the subdivision in fibre supplementation was made after completion of the study, baseline characteristics were compared statistically to exclude differences that were already present at the start. No statistical differences were found for baseline data (Table 1) and therefore these groups can be regarded as similar for these characteristics.

Statistics

Data are presented as mean and standard deviation (s.d.). Statistics were performed with a two-way Anova for repeated measures to study differences over time and with respect to the fibre supplementation. Changes in parameters measured with respect to the initial value were calculated as a percentage of the initial value to correct for differences in initial level of the parameter at the start of the experiment. Statistical significance was set at $P < 0.05$.

Results

The physical characteristics of the subjects before the study (Table 1) were not statistically different among the three groups. Weight maintenance and weight relapse for the three groups are presented in Figure 1 which illustrates the weight gained in the different groups at 16 months. Nine of the ten subjects from group B had regained 50% or more of the weight lost during the VLCD. In group A, 6 out of 10 subjects had regained 50% or more, and for the control group 7 out of 11 subjects regained 50% or more. On average the percentage of regain at 16 months was 65% (±65%) for group A; 123% (±63%) for group B and 61% (±66%) for the control group. Although there is a wide variation in weight regain, this difference in relapse between the three groups was almost significant ($F(2,30)=2.926$; $P=0.07$). Expressed as change with respect to the initial value, changes in body weight are shown in Figure 2. The amount of regain of BW was higher for group B compared to group A and the control group at four months ($P=0.08$) and was significantly higher at 10 months (Figure 2). The percentage BW at 16 months was lower for group A

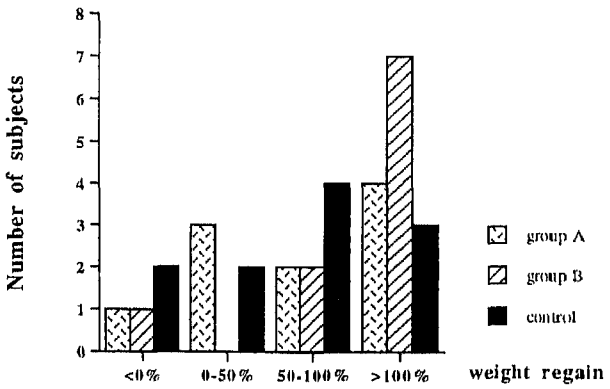

Figure 1 Weight regain at 14 months after VLCD. Weight regain is presented as a percentage of the amount of weight lost during VLCD. The VLCD intervention resulted in a significant weight loss for all three groups. The amount of weight lost during the VLCD was set at 100%. The number of subjects of the three groups that gained different amounts of BW are presented.

Table 1 Baseline characteristics

Parameter	*All*	*Group A*	*Group B*	*Control*	*P*
Number	31	10	10	11	
Age (y)	41.4 (7.4)	44.8 (7.3)	38.9 (7.0)	40.5 (7.1)	0.18
BW (kg)	88.7 (10.4)	89.8 (12.0)	87.0 (5.9)	89.4 (12.6)	0.82
Height (m)	1.64 (0.06)	1.62 (0.06)	1.64 (0.05)	1.65 (0.09)	0.70
BMI (kg/m^{-2})	33.2 (3.7)	33.9 (2.8)	32.7 (3.6)	32.9 (4.7)	0.75
BPsys (mm Hg)	135 (17)	145 (23)	129 (16)	133 (10)	0.12
BPdia (mm Hg)	94 (11)	96 (14)	90 (9)	96 (7)	0.34
W/H	0.83 (0.05)	0.85 (0.04)	0.82 (0.06)	0.84 (0.06)	0.63
Body fat (%)	43.0 (4.1)	42.6 (4.4)	43.7 (3.6)	42.6 (4.5)	0.78
Sag. dia. (cm)	23.8 (2.2)	24.0 (2.4)	23.6 (1.3)	23.7 (2.7)	0.91

The data of all 31 subjects before the study are presented and compared for the three groups. In group A the subjects consumed > 80% of the fibre supplied. In group B the subjects consumed between the 50–80% of the fibre supplied. The control group did not receive a supplement. No statistical differences were found in baseline characteristics among the three groups. Mean and standard deviations are presented. The *P*-values of the Anova-factor analysis are presented.

Table 2 Anthropometric data

Month	*0*	*2*	*4*	*10*	*16*
Body weight (kg)					
A	89.8 (12.0)	78.6 (10.2)	78.0 (10.6)	80.9 (12.5)	85.6 (13.1)*
B	87.0 (5.9)	77.3 (6.1)	79.2 (7.4)	85.3 (9.8)	88.4 (10.1)*
C	89.4 (12.6)	78.3 (10.6)	78.4 (10.4)	81.1 (10.6)	85.0 (12.0)*
BMI (kg/m^{-2})					
A	33.9 (2.8)	29.7 (2.3)	29.5 (2.6)	30.5 (3.6)	32.3 (3.7)*
B	32.7 (3.6)	29.0 (3.3)	29.8 (3.8)	32.0 (4.8)	33.2 (5.0)*
C	32.9 (4.7)	28.8 (3.8)	28.9 (3.7)	29.9 (4.0)	31.4 (5.1)*
Body fat % (%)					
A	42.6 (4.4)	37.3 (3.7)	36.2 (2.7)	38.5 (4.4)	42.1 (3.3)*
B	43.6 (3.8)	38.7 (5.8)	38.2 (6.3)	39.9 (5.7)	44.6 (4.5)*[a]
C	42.6 (4.5)	36.4 (6.0)	34.6 (5.9)	35.7 (5.1)	38.9 (5.1)*
WHR					
A	0.85 (0.04)	0.82 (0.05)	0.81 (0.05)	0.82 (0.04)	0.82 (0.04)*
B	0.82 (0.06)	0.80 (0.05)	0.81 (0.04)	0.81 (0.06)	0.83 (0.05)*
C	0.84 (0.06)	0.79 (0.05)	0.81 (0.05)	0.81 (0.05)	0.83 (0.04)*

Data of 31 subjects are presented at different time points. Mean and standard deviations are presented. Body weight (BW) is presented in kg; Body mass index (BMI) in kg/m^{-2}; body fat percentage in percentage; waist-hip ratio (WHR) has no unit. For all anthropometric data presented the differences over time were significant, which are indicated by *. Between groups only body fat percentage at 14 months differed significantly between group B and the control group ([a]).

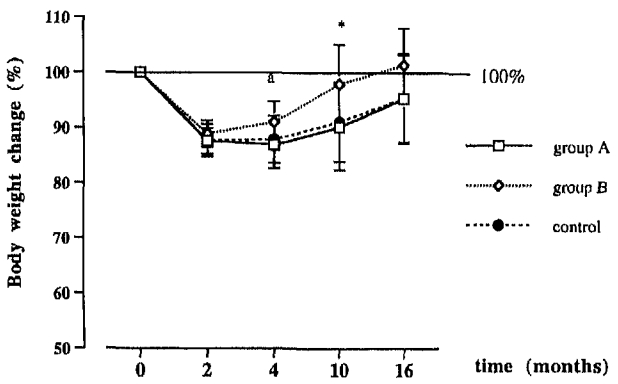

Figure 2 The changes in body weight are expressed as percentage of the initial value for group A (open squares), group B (open diamonds) and for group C (filled circles). The mean and standard deviation are presented at different time points measured, for the three groups. The rate of regain is faster for the fibre B group than for the fiber A and control group. a = fibre B differed at $P = 0.08$ from group A and control group. *$P < 0.05$ significant difference between fibre B and fibre A and the control group.

and the control group lower than at the beginning of the study ($P = 0.09$), but was equal with the initial BW for group B (Figure 2). Body weight, body mass index, body fat percentage and waist-hip ratios measured at different time points are presented in Table 2. Only body fat percentage was significantly higher at 16 months after the VLCD period in the fibre B group than in the control group. Blood pressure did not change significantly with fibre supplementation (data not shown). Baseline data of blood parameters are presented in Table 3, and during the course of the study no differences were found between the groups. Blood cholesterol, glucose and insulin levels were not affected by fibre supplementation.

The mean energy intake levels of the three groups changed significantly over time from 6.8 ± 2.2 MJ at baseline to 5.3 ± 1.7 MJ after VLCD, and showed a tendency for differences in energy intake between groups ($F(2,23) = 3.05$; $P = 0.07$). At 16 months only group A showed a lower energy intake (5.8 ± 1.8 MJ) than the other two groups (7.0 ± 2.2 MJ for group B and 6.6 ± 1.5 MJ for group C) but this was not significantly different. Group A also showed lower energy intake levels (5.8 ± 1.8 MJ) compared with baseline (7.2 ± 3.3 MJ); this difference was however not significant ($P = 0.11$).

Eating behavior characteristics were of special interest because the deviation in two groups in the

Table 3 Blood parameters

Parameter	*Group A*	*Group B*	*Control*	*P*
Number	10	10	11	
Glucose ($mmol/L^{-1}$)	5.1 (0.6)	5.0 (0.4)	5.0 (0.6)	0.90
Insulin (mU/L^{-1})	13.2 (4.2)	12.9 (4.4)	12.9 (6.9)	0.99
Total cholesterol ($mmol/L^{-1}$)	5.7 (0.5)	6.1 (0.9)	5.2 (0.8)	0.04
High density lipoprotein ($mmol/L^{-1}$)	1.3 (0.3)	1.5 (0.3)	1.5 (0.7)	0.49
Low density lipoprotein ($mmol/L^{-1}$)	3.6 (0.7)	3.6 (1.0)	3.0 (0.7)	0.17
Apoprotein-A1 (mg/dl^{-1})	119.8 (19.9)	143.8 (24.9)	122.7 (44.0)	0.19
Apoprotein-B (mg/dl^{-1})	85.3 (13.1)	85.8 (17.6)	71.2 (14.2)	0.07
Lipoprotein(a) (mg/dl^{-1})	243 (351)	230 (192)	180 (242)	0.86

Baseline blood parameters are shown for the three groups. Total cholesterol, HDL and LDL data are presented for the three groups in $mmol/l^{-1}$. Apoprotein-A1, Apoprotein-B and Lipoprotein (a) are presented in mg/dl^{-1}. The blood glucose and insulin data are also shown. Mean and standard deviations are presented. The *P*-values of the Anova-factor analysis are presented.

Table 4 Eating behavior characteristics

Month	*0*	*2*	*4*	*10*	*16*	*P*
TFEQ-factor 1						
A	10.3 (2.7)	14.7 (2.7)	17.2 (2.3)[a]	14.1 (3.9)	13.7 (4.0)	*
B	9.0 (4.8)	14.2 (4.0)	13.0 (5.6)	10.8 (5.0)	9.1 (5.6)	*
C	9.4 (5.3)	14.5 (3.4)	14.5 (4.1)	12.8 (4.8)	10.8 (4.9)	*
TFEQ-factor 2						
A	8.1 (4.0)	5.8 (4.3)	5.6 (3.6)	6.0 (4.6)	6.6 (3.9)	NS
B	8.8 (2.4)[b]	7.4 (3.9)	7.3 (3.4)	8.6 (2.9)[b]	8.4 (2.6)	NS
C	5.7 (3.0)	5.8 (3.2)	5.1 (3.0)	5.1 (2.7)	6.0 (3.4)	NS
TFEQ-factor 3						
A	5.4 (3.1)	3.0 (2.5)	3.2 (2.1)	4.0 (3.7)	3.2 (3.2)	*
B	6.9 (2.9)	4.0 (4.1)	5.1 (4.3)[b]	6.1 (4.1)	6.1 (4.1)	*
C	4.1 (3.3)	3.0 (2.7)	2.0 (2.1)	2.6 (2.5)	4.0 (2.8)	0.08

Factor 1, 2 and 3 scores of the Stunkard and Messick Three Factor Eating Behavior Questionnaire (TFEQ) (1985) of the three groups are presented at all time points. Significant differences over time are presented (*) and between groups. [a]Difference with $P=0.06$ between group A and control group; [b]difference with $P=0.07$ between group B and control group.

fibre supplemented group, by means of degree of compliance, was thought to be related to eating behavior characteristics. The variation in these factors between the subjects, also within each group, resulted in comparable eating behavior characteristic scores. In Table 4 the restraint score (factor 1), the emotional/control score (disinhibition = factor 2) and the hunger related scores (factor 3) are presented. Only group A at month 16 showed significantly increased restraint scores from baseline ((0): 10.2 ± 2.7 *vs* (16): 13.7 ± 4.0). In this group the factor 3 scores at the end of the study were also significantly lower at 16 months ((0): 5.3 ± 3.1 *vs* (16) 3.2 ± 3.2). These changes in scores were not found for group B and the control group. Changes in eating behavior characteristics over the whole study period were not related to compliance of fibre intake. Changes in eating behavior factors were also studied in relation to the amount of weight gain for that period (change in factor and body weight from start of the study to month 2 (1); from start to month 4 (2); from start to month 10 (3); and from start to month 16 (4)). When the whole group was studied, significant relations were found between the amount of change in factor 1-score and the change in BW. This was found for the period from month 0 to month 4 ($r_2 = 0.51$); from month 0 to month 10 ($r_3 = 0.60$) and from month 0 to month 16 ($r_4 = 0.49$). None of these relations were found with the other factors for the whole group. When the groups were analysed separately the main result was the significant relation in group A between the amount of change in factor 2 and the amount of body weight change ($r_1 = 0.70$; $r_2 = 0.71$; $r_3 = 0.73$; $r_4 = 0.18$). The last period was not significant. These relations were not seen for the other two groups.

Discussion

Weight maintenance

In the present study no effect of 20 g of guar gum supplementation per day was found on long-term weight maintenance, blood pressure, blood cholesterol or any other relevant parameter investigated. The control group showed the same physiological changes as the fibre supplemented groups. Weight maintenance was even better achieved in the control group than in the fibre B group; 4 subjects of group A; 1 subject of group B and 4 of the control subjects were able to avoid regaining more than 50% of the weight lost during VLCD.

Other long-term fibre supplementation studies (Table 5) show conflicting results with respect to body weight changes when fibre was supplemented.

Table 5 Long-term fibre supplementation studies

N/sex	*Amount*	*Fibre*	*Period*	*BW*	*BP*	*Chol.*	*Reference*
Diet and fibre supplementation							
97f	6 g	insoluble	12 mo	d	dia d	?	Ryttig[10]
41f	7 g	insoluble	3 mo	d	dia d	?	Rösser[27]
41f/11m	7 g	insoluble	6 mo	d	=	?	Rigaud[19]
Fibre supplementation							
26f/13m	15 g	guar gum	13 mo	d	d	7%d	Uusitupa[28]
8f/9m	18 g	guar gum	12 mo	=	?	15%d	Simons[30]
32f	15 g	guar gum	4 mo	d	?	no	Tuomilehto[29]
31f	20 g	guar gum	14 mo	=	=	=	Pasman (this paper)

Outline of several long-term fibre supplementation studies. Study characteristics in number of subjects, subject gender (m = male; f = female), amount of fibre supplemented, type of fibre, duration of the study, effect found at body weight (BW), blood pressure (BP) and at cholesterol (chol.) are presented. Abbreviations/symbols used: d = decreased; = no effect; ? no information available; dia d = diastolic blood pressure is decreased.

In this study we used a partially hydrolyzed fibre, which was not very well dissolvable after processing. The normally bitter taste of the guar gum fibre was gone, and gel-forming did not occur in the solution. The amount of fibre supplemented (20 g of fibre daily) was the same, or even higher, as was used in other studies (Table 5). Comparison with other fibre supplemented studies requires additional information about the diet instructions given. In our study, subjects were eating *ad libitum* in the weight maintenance phase, to investigate the sole effect of the fibre supplement under normal free living conditions, when on average already 18–19 g of dietary fibre was consumed. In the studies of Rigaud, Ryttig and Rössner and coworkers, besides a fibre supplement an energy restricted diet of 5–6 MJ/d^{-1} was prescribed.[10,19,27] The restricted energy intake by itself could result in a lowered BW, but addition of fibre was still more effective. Ryttig and coworkers[10] further reported that at the end of their study subjects were also allowed to eat *ad libitum*. The fibre supplement was still effective and resulted in a further decrease of BW.

Differences in fibre preparation used could also be an explanation for differences in results found. The study of Uusitupa and colleagues[28] is comparable with our study with respect to the amount of fibre supplemented, fibre type and duration of supplementation. The consumption of the granules before each meal (dissolved in a drink) might be more effective at reducing the consumption of the main meal and result in a lowered energy intake and finally weight loss. Also the amount of solution used for dissolving the fibre might result in different results, affecting feelings of fullness and satiation as an interfering factor. In the study of Tuomilehto and coworkers[29] the fibre granules were also supplied before each meal. The consumption of 15 g of guar gum daily for four months significantly decreased body weight by 2.5 kg. In our study, subjects consumed the fibre dissolved in a solution in the afternoon and in the evening, between the main meals to reduce energy intake from snacks. In contrast to earlier findings in a short-term study, our fibre supplement did not seem to be effective for long-term maintenance of energy balance. The ineffectiveness of the fibre supplement in maintaining the reduced body weight in our study is comparable with Simons *et al.*[30] Their study was mainly focused upon the cholesterol lowering effect of fibre, but they also reported that body weight did not change significantly after 12 months treatment with 18 g of fibre.

Free living conditions

In the present study subjects were not restricted or advised with respect to energy intake and energy expenditure. It would be very difficult for fibre supplementation, as the sole intervention, to be effective for weight maintenance when subjects are free living. Social events, work, family and other aspects of life interfere with food consumption. Complete changes in behaviour with respect to food intake and exercise seem to be necessary for successful weight maintenance or prevention of weight gain.[31] Studies that investigated the needs of successful weight maintainers showed that exercise motivation, social support, and knowledge of food are important factors.[2,4,5] Supplementation of fibre, an aspect of healthy food consumption, would be too weak on its own, more factors should be stimulated for an effective weight maintenance.

A problem with a long-term intervention is the duration of the study. Subjects are not able to adhere closely to a certain strategy, when not supervised strictly. Already after 10 months we found poor weight maintenance results.[32] Habituation and compliance are of importance in long-term intervention studies.

Another possible explanation for the fact that no effect of fibre was found at weight maintenance, could be the level of energy intake. In a short-term fibre supplementation study we found that fibre supplementation was effective at an energy intake level of ± 5 MJ/d^{-1}.[17] The energy intake in the present study was not high, but could be above the 'effective level. In this study probably 8–9 MJ/d^{-1} was consumed (based upon the measured resting metabolic rate (data not shown) and an assumed physical activity index of 1.4, resulting in a percentage of underreporting of 33%, a figure that has been reported before for obese).[33] Astrup and colleagues[34] also found that fibre supplementation was effective at low energy intake levels, because compliance to a very low calorie diet intervention improved when fibre was supplemented. Reduced hunger scores and increased satiety scores enabled subjects to fulfil the diet intervention.[34] The first three studies as presented in Table 5 of Ryttig, Rössner and Rigaud and colleagues further support the effectiveness of fibre supplementation when energy intake is below 6 MJ/d^{-1}.[10,19,27]

Habituation

Habituation to fibre intake may be an explanation for the fact that no effect of the fibre was found, as was also seen in the study of Simons *et al.*[30] In their study the main changes in cholesterol were found in the first three months of the study. In the following 10 months no further changes were seen. We showed in an earlier study that supplementation of fibre for one week, resulted in significantly lowered energy-intake and increased satiety feelings at already low energy intake levels.[17] In the present study subjects had difficulties with consequent fibre consumption, because the effect on hunger and satiety was not felt as clear as in the beginning (habituation). From colonic metabolism studies it is already known that bacterial mass and activity is higher after chronic load of nonabsorbable sugars.[35] Alternating intake of fibre

to prevent habituation, as suggested by Flatt (per. comm., 1994), might result in stronger effects of fibre.

Eating behavior

In the present study not only is fibre supplementation a factor that could affect weight maintenance, (change in) eating behaviour is also an influencing factor. The results of this study suggest that a change in cognitive restraint score (F1) is related to weight change. The larger the change in cognitive restraint, namely the change in attitude towards eating, the better the subjects are able to maintain body weight, as we have reported previously.[36] The decrease in factor 2 score (disinhibition, emotional eating and control) may have contributed to the maintenance of body weight in the long-term for group A. This decrease in disinhibition mirrors compliance, and coincides with better weight maintenance in group A than in group B (Figure 1). The control group showed the same weight regain pattern as group A did, but no changes in factor 2 scores, probably because they were not subjected to an intervention and there was no reason for a change in disinhibition. The small changes in factor 1 and factor 2 scores in group B mirror the poor compliance of this group.

Conclusions

The supplementation of the water soluble fibre did not result in a better weight maintenance of the fibre supplemented subjects. Not only is fibre intake an important factor for weight control, eating behavior, activity level, social circumstances, etc. all influence body weight. An addition of 20 g of fibre daily might be overruled by other factors in a long-term project with free living subjects where social factors are involved. The level of energy intake (up to 5 MJ/d^{-1}) at which fibre supplementation would have been effective, concluded from our previous short-term study, was not maintained. So, in the long-term, fibre might be effective if combined with a 4–5 MJ/d^{-1} energy intake, a high compliance rate, and if habituation is prevented by means of irregular intake.

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