Introduction

The optimal composition of a diet for patients with type 2 diabetes has been a subject of much debate. A vegetarian diet is an interesting alternative different from conventional diabetic diets. Observational trials showed that prevalence of type 2 diabetes is twice lower in vegetarians compared to common population, even after adjustment for differences in body-
mass index (BMI) [1,2]. Randomized clinical trials demonstrated that a vegetarian diet leads to a greater weight loss and reduction in fasting plasma glucose compared to a conventional diabetic diet [3], and also to a greater reduction in HbA1c, LDL-cholesterol and a greater reduction in hypoglycemic agents [4]. Our previous 6-month randomized study had demonstrated that a vegetarian diet more effectively leads to a reduction in insulin resistance, in the volume of both visceral and subcutaneous fat and improvement of markers of oxidative stress and adipokines than a conventional diet [5].

However, successful weight and glycemic control maintenance following initial weight loss intervention is challenging for most of the people. Successful weight maintenance is associated with more initial weight loss, reduction in fasting insulin and insulin resistance [6,7]. This would suggest that the vegetarian participants in our study should be able to maintain their reduced weight and improved glycemic control more than the participants consuming a conventional diet.

The aim of this post-trial monitoring was to follow up our patients at 6 months and 1 year from the end of the intervention.

Material and methods

**Intervention**

The methods of the 6-months randomized study are described in detail elsewhere [5]. Briefly: 74 subjects with type 2 diabetes treated by oral hypoglycemic agents were randomly assigned into one of two groups within the framework of an open parallel randomized study. The vegetarian group (V, n = 37) consumed a lacto-ovo-vegetarian diet, whereas the control group (C, n = 37) consumed a conventional diabetic diet. The conventional diabetic diet contained about 45% of energy in the form of carbohydrates, 30% of fats and 25% of proteins. The upper limit for the intake of cholesterol was 200 mg daily. The vegetarian diet contained about 15% more carbohydrates, less fat, and the intake of cholesterol was up to 50 mg a day. The participants in both groups were prescribed an individual caloric restriction of –500 kcal/day based on measurement of resting energy expenditure by indirect calorimetry. The participants were examined at start, after 3 months of diet intervention and the subsequent 3 months of diet + exercise intervention (when diet was combined with aerobic exercise three times a week for one hour at 60% of maximal heart rate).

**Follow-up**

62 patients (31 from V and 31 from C) who completed the study were invited for a follow-up at 6 months and 1 year after the end of the intervention. 47 patients (76%; 23 from V and 24 from C) attended the 6-month-follow-up, 44 (71%; 21 from V and 23 from C) attended the 1-year follow-up. During one year after the end of the intervention, the patients had discontinued the original diet intervention and they consumed comparable diets. We measured their weight, waist circumference, HbA1c and blood lipids. The patients completed a 3-day dietary record and their physical activity was assessed by an Omron HJ-113 pedometer (Omron, Kyoto, Japan).

The study protocol was approved by the Institutional Ethics Committee.

For statistical analysis, we used a repeated measures ANOVA model with between-subject and within-subject factors and interactions. Within each group, paired comparison t tests were calculated to test whether the changes from the end of the intervention (6 months) to 12 months and from 6 to 18 months were statistically significant.

**Results**

**Diet and physical activity:** Parameters of dietary intake and pedometer readings are given in Table 1. We did not observe any differences between the groups in either parameter.

**Oral hypoglycemic agents**, which were reduced by 43% in V vs. by 5% in C during the intervention, had to be increased by 14% (3/21) in V and by 26% (6/23) in C during 1 year after the end of the intervention. Insulin therapy was started in 5% participants (1/21) in V and in 13% (3/23) in C (Fig. 1A).

**Body weight**, which was reduced more in V during the intervention (−6.2 ± 5.8 kg vs. −3.2 ± 4.5 kg in C; group × time p = 0.001), increased (p ≤ 0.05) slightly 6 months after the intervention in both groups (+1.7 ± 3.1 kg in V and +1.5 ± 3.1 kg in C; group × time p ≤ 0.05). One year after the end of the intervention, the trend toward weight gain was not statistically significant in either group (Fig. 1B).

| Table 1 – Dietary intake and pedometer readings during the post-trial monitoring. |
|-----------------|-----------------|-----------------|-----------------|
| Dietary intake  | Vegetarian group | Control group    | p-Value         |
| Caloric intake  | 1734 ± 477      | 1786 ± 641      | 0.90            |
| Carbohydrates – g day⁻¹ | 253 ± 81 | 239 ± 93 | 0.460 |
| Fats – g day⁻¹ | 78 ± 31         | 81 ± 37         | 0.520           |
| Proteins – g day⁻¹ | 83 ± 23 | 86 ± 21 | 0.18 |
| Fiber intake – g day⁻¹ | 25 ± 10 | 24 ± 10 | 0.790 |
| Cholesterol intake – mg day⁻¹ | 232 ± 114 | 288 ± 179 | 0.16 |
| Pedometer readings (average steps/day) | 5044 ± 2002 | 4966 ± 2416 | 0.93 |

Data are means ± SD. Listed p values are for interaction between group and time. Data were collected 6 months post intervention (month 12) and 1 year post intervention (month 18).
Waist circumference, which was reduced more in V during the intervention (−8.7 ± 4.7 cm vs. −4.7 ± 4.7 cm in C; group × time $p = 0.001$), increased 6 months after the end of the intervention in V (+1.9 ± 2.7 cm; $p < 0.01$), while the trend toward increase was not statistically significant in C (group × time $p \geq 0.01$). One year after the end of the intervention, the trend toward increase was not statistically significant in either group (Fig. 1C).

HbA1c, which was reduced more in V during the intervention (−0.7 ± 1% vs. −0.2 ± 1% in C; group × time $p = 0.08$),
increased 6 months after the end of the intervention in V (±0.7 ± 0.9%; p < 0.01), while the trend toward an increase was not statistically significant in C. One year after the intervention, the increase in HbA1c was comparable in both groups (±0.49 ± 1.04%; p = 0.05 in V vs. ±0.42 ± 0.8%; p < 0.05 in C; group × time p = 0.31; Fig. 1D).

Blood lipids: Hypolipidemic agents were discontinued after the end of the intervention in 29% patients (6/21) in V and in 0% (0/23) in C. LDL cholesterol, which decreased during the study only in V (–0.2 ± 0.6 mmol/l; p = 0.05), did not change significantly in either group either 6 months or 1 year after the end of the intervention, although a trend toward an increase was evident in both groups (Fig. 1E). Total cholesterol, HDL-cholesterol nor triglycerides changed significantly in either group either at 6 months or 1 year after the end of the intervention.

Discussion

In spite of the diminution of benefit 6 months after the end of the intervention, the positive effects of a vegetarian diet compared to a conventional hypocaloric diet were still persisting 1 year after the end of the intervention with regards to body weight and waist circumference, although the patients did not continue in their originally assigned diets and they consumed a comparable diet for 1 year after the end of the intervention (although it is possible that some vegetarian participants may have maintained some of the healthful dietary habits they adopted during the intervention). Blood lipids did not change significantly in either group while the hypolipidemic agents were discontinued in almost one third of the patients originally assigned to a vegetarian diet. HbA1c increased comparably in both groups while oral hypoglycemic agents were increased and insulin therapy was started almost twice more in patients originally assigned to a conventional diabetic diet.

Observational and clinical trials indicate a benefit of a vegetarian diet for cardiovascular prevention and diabetes management. Vegetarian diet is a well respected alternative to conventional dietary interventions in both prevention and treatment of diabetes according to international recommendations [8,9], lately also in the Czech Republic [10]. It is important that it is performed under professional supervision of a skilled physician and a registered dietician.

Several possible mechanisms may explain the beneficial effects of vegetarian diet for diabetes management [11]: higher intake of fiber [12], lower intake of saturated fat (and a higher P/S ratio) [13], higher intake of non-heme iron and reduction in iron stores [14], higher intake of vegetable protein in place of animal protein [15], higher intake of antioxidants [16] and plant sterols [17].

On the other hand, an inappropriately planned vegetarian (especially a strict vegan) diet may lead to a deficiency of vitamin B12, calcium, vitamin D and zinc. An experienced registered dietician can add up invaluable contribution, giving the patients advice which foods are a good source of these objectionable vitamins and minerals [18].

Our results indicate a partial persistence of the positive effects of a vegetarian diet compared to a conventional hypocaloric diet 1 year after the end of the intervention. The persistence of the beneficial effects could not be explained by readily measurable differences in dietary intake or in pedometer records. A possible mechanism of this observation could be the so-called metabolic memory [19,20] although we did not measure oxidative stress markers or advanced glycation end products during the post-trial monitoring to support this hypothesis.

Conclusions

Our study showed that even a short-term lifestyle intervention elicits marked positive effects on glycemic control and cardiovascular risk factors in a longer term in patients with type 2 diabetes. One year after the end of a 6-month-intervention, the beneficial effects of a vegetarian diet compared to a conventional diet were partially maintained.

Conflict of interest

None to declare.

Funding body

This work was supported by the grant of Ministry of Health MZ CR NT/11238-4 and by the project (Ministry of Health, Czech Republic) for development of research organization 00023001 (IKEM, Prague, Czech Republic) – Institutional support.

Ethical statement

The study protocol was approved by the Institutional Ethics Committee.

Informed consent

The patients signed an informed consent and agreed to participate in the study.

References