



ORIGINAL ARTICLE

Total cardiovascular risk profile of Taiwanese vegetarians

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Background: Although the health benefits of vegetarian diets have been well documented among Western population, there are geographic differences of vegetarian diets and the health benefits of the Taiwanese vegetarian diet have not been studied extensively. In addition to conventional risk factors, homocysteine and high-sensitivity C-reactive protein (hs-CRP) levels have been found to predict first atherothrombotic events. We undertook this study to examine the total risk profile of Taiwanese vegetarians.

Methods: A total of 198 healthy subjects (99 vegetarians and 99 omnivores) were recruited. Fasting blood samples were analyzed for glucose, cholesterol, triglyceride, high-density lipoprotein cholesterol (HDL-C), low-density lipoprotein cholesterol (LDL-C), white blood cell count, hs-CRP and homocysteine.

Results: There was no significant difference in age, body mass index, blood glucose, white blood cell count, triglyceride and HDL-C between the two groups. The vegetarian group had significantly more females (65.7 vs 46.5%); lower body weight (58.66 ± 11.13 vs 62.88 ± 12.24 kg); shorter height (159.14 ± 7.88 vs 162.53 ± 8.14 cm); lower total cholesterol (184.74 ± 33.23 vs 202.01 ± 41.05 mg/dl); and lower LDL-C (119.63 ± 31.59 vs 135.89 ± 39.50 mg/dl). Hs-CRP was significantly lower (0.14 ± 0.23 vs 0.23 ± 0.44 mg/dl, $P = 0.025$), whereas homocysteine was significantly higher (10.97 ± 6.69 vs 8.44 ± 2.50 μ mol/l, $P = 0.001$) in vegetarians than omnivores.

Conclusions: Taiwanese vegetarians have lower total cholesterol, LDL-C and hs-CRP levels, and higher homocysteine levels than omnivores. Owing to different predictive value of each risk factor, the Taiwanese vegetarians had a better cardiovascular risk profile than omnivores. Whether the Taiwanese vegetarian diet should be supplemented with vitamin B₁₂ to lower serum homocysteine level remains to be addressed.

European Journal of Clinical Nutrition advance online publication, 14 March 2007; doi:10.1038/sj.ejcn.1602689

Keywords: Taiwanese; vegetarian; atherosclerosis; hs-CRP; homocysteine

Introduction

The benefits of vegetarian diets

The health benefits of vegetarian diets have been well documented in Western population. The most prominent benefits relate to the cardiovascular system. A vegetarian diet

reduces overall mortality, especially cardiovascular and cancer mortalities. It lowers serum cholesterol and low-density lipoprotein (LDL) levels and hence reduces atherosclerosis. It lowers blood pressure and reduces the risk for type II diabetes. Dietary fibers improve sensitivity to insulin. Vegetarians were found to have a lower incidence of gastrointestinal cancer, gallstones, diverticular diseases, constipation and even a lower emergency appendectomy rate. A vegetarian diet decreases the prevalence of chronic diseases, medication, and health services use (hospitalization and X-ray), and potentially, healthcare costs (Lin, 1997).

Geographical differences of vegetarian diets

Vegetarian diets are generally characterized by the more frequent consumption of fruits, vegetables, whole grains, legumes and nuts, which results in higher intakes of dietary

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Contributors: C-WC provided the initial idea and drafted the manuscript, C-LL reviewed the literature, developed the design and revised the manuscript; all authors subsequently collected, analyzed the data and have seen and approved a final revised version.

Received 2 July 2006; revised 9 January 2007; accepted 10 January 2007

fiber, antioxidants and phytochemicals compared to non-vegetarian diets, although not all vegetarian diets are the same. As a result, cross-sectional studies of the health outcomes of vegetarians from different geographic areas could yield different results owing to differences in the intakes of nutrients and non-nutrients, which have been shown in clinical or experimental studies to have significant impacts on health, such as fiber, polyunsaturated fatty acids, especially long-chain polyunsaturated fatty acids, such as eicosapentaenoic acid, docosahexaenoic acid, monounsaturated fatty acids, milk (casein, the milk protein, and whey) and phytochemicals, such as allicin (in garlic), polyphenols (in cocoa), isoflavones (in soy) and anthocyanins (in red wines and grape juice) (Rajaram, 2003).

Taiwanese vegetarians

In Taiwanese society, vegetarianism originates from the Buddhist teaching of 'no killing' and has been practiced for centuries. Most people eat small amounts of dairy products and eggs in addition to plant food (ovo-lactovegetarians) (Lin *et al.*, 1997). In Taiwan, 2.3% of men and 4.4% of women above 45 years of age are vegetarian (Tzeng *et al.*, 1999). The modern Buddhist vegetarian diet is similar to the usual Taiwanese diet in terms of meal pattern, cooking methods, choice of staple (primarily rice), as well as fruit and vegetable consumption, except that no meat, fish or poultry is consumed (Pan *et al.*, 1993). The Taiwanese vegetarian diet includes a large intake of soybean products, which are the major substitute for animal products (Lu *et al.*, 2000). On the basis of a nutritional survey, Taiwanese vegetarians consumed fewer calories, more carbohydrate (63% of calories in men, 58% in women), less protein (12% of calories) and less fat (25% for men, 30% for women) (Lu *et al.*, 2000). The polyunsaturated/saturated (P/S) and polyunsaturated/monounsaturated (P/M) fatty acid ratios in the Taiwanese vegetarian diet were high (P/S=3.4, P/M=2.5) (Pan *et al.*, 1993; Lu *et al.*, 2000). The mean P/S ratio in the vegetarian diet was about twice that of the omnivore diet (Lu *et al.*, 2000). Although the health benefits of the Taiwanese vegetarian diet have not been studied extensively, it has been reported to improve insulin sensitivity (Kuo *et al.*, 2004) and vascular dilatatory and endothelial functions (Lin *et al.*, 2001).

Conventional cardiovascular risk factors

Traditionally, the benefits of vegetarian diets have been attributed to lower levels of serum cholesterol and LDL cholesterol (LDL-C) (Krajčovičová-Kudláčková *et al.*, 1994). However, other factors present in the vegetarian diet may also play important roles. For example, vegetables are rich in natural antioxidants that may protect vegetarians from developing cardiovascular diseases. In fact, the oxidative modification of LDL is an important event in atherogenesis. In vegetarians, thiobarbituric acid-reacting substances in native and oxidative modified LDL were significantly lower,

and plasma total antioxidant status was significantly higher, which implies that vegetarians' LDL-C is more resistant to oxidation (Nagyová *et al.*, 1998). Recently several emerging plasma biomarkers have been shown to predict first atherothrombotic events; homocysteine and high-sensitivity C-reactive protein (hs-CRP) appear to be the most important such biomarkers (Ridker *et al.*, 2004).

Homocysteine

Clinical studies indicate that elevated levels of homocysteine are associated with atherosclerosis. Homocysteine stimulates vascular smooth muscle cells to proliferate and to synthesize collagen; it also affects endothelial cell function and adversely affects the anticoagulant system, which may in part explain its atherogenicity (Harpel, 1997). Hyperhomocystinemia has been shown to be an independent cardiovascular risk factor (Clarke and Stansbie, 2001) and prospectively elevated plasma homocysteine is associated with increased total and cardiovascular mortality, increased incidences of stroke, dementia and Alzheimer's disease, bone fracture, and higher prevalence of chronic heart failure (Selhub, 2006). However, even though vegetarians generally have better cardiovascular risk profiles, serum homocysteine has been reported to be higher in vegetarians than in omnivores because of a relative vitamin B₁₂ deficiency (Krajčovičová-Kudláčková *et al.*, 2000).

High-sensitivity C-reactive protein (hs-CRP)

Atherosclerosis is not only a disease in which there is accumulation and oxidation of cholesterol and LDL-C, but it has also been shown to be a chronic inflammatory process (Danesh *et al.*, 1998). There is a strong relationship between systemic inflammation and cardiovascular events (Mendall *et al.*, 2000; Albert *et al.*, 2003). It is now generally accepted that there is a positive association between hs-CRP and the development of ischemic heart disease, cardiovascular mortality, and a variety of established cardiovascular risk factors (Ridker *et al.*, 1997). Several large-scale prospective epidemiological studies have shown that the plasma hs-CRP level is a strong independent predictor of risk for future myocardial infarction, vascular death and stroke (Kuller *et al.*, 1996; Ridker *et al.*, 2000). Ridker *et al.* (2000) recommended that hs-CRP testing should be added to standard lipid screening to improve global risk prediction among those with both high and low cholesterol levels).

In this study, we compared serum homocysteine and hs-CRP levels, as well as conventional risk factors between Taiwanese vegetarians and omnivores to define better the cardiovascular protective effects of Taiwanese vegetarian diets.

Patients and methods

All subjects were adults (more than 20-years old), and had undergone a general health examination at the Buddhist

Dalin Tzu-Chi General Hospital from 12 December 2004 to 25 March 2005. The subjects filled out questionnaires regarding their past medical history, dietary preferences and their willingness to participate in the study and were enrolled if they met the inclusion criteria; they were enrolled on a 'first come, first served' basis until the number in both groups (99 vegetarians and 99 omnivores) were filled. Patients with a history of diabetes, hypertension, cerebrovascular disease, dyslipidemia, chronic gingivitis, rheumatoid arthritis or other connective tissue disease, diagnosis of coronary artery disease, and fever or other infectious disease within 3 weeks before the start of the study were excluded. Patients who had been on an ovo-lacto-vegetarian diet for at least 1 year were enrolled into the vegetarian group. After an overnight fast (for more than 12 h), venous blood samples were obtained from 99 vegetarians (group A) and 99 omnivores (group B). All patients signed informed consents, and the study protocol was approved by the research committee and the institutional review board (IRB) of The Buddhist Dalin Tzu-Chi General Hospital.

We recorded the patients' weight, height and blood pressure. Blood samples were immediately tested after being taken for hs-CRP, glucose, cholesterol, triglyceride, high-density lipoprotein cholesterol (HDL-C), LDL-C, white blood cell (WBC) count and homocysteine. Hs-CRP was assayed using an enzyme-linked immunosorbent assay (ELISA), based on purified protein and polyclonal anti-C-reactive protein antibodies (Denka Seiken Co. Ltd, Tokyo, Japan). Homocysteine was assayed using an immunoassay method (FPIA assay; AXSYM System, Abbott Laboratories, Chicago, IL, USA).

Statistical analysis

The commercially available SPSS 11.5. statistical software package (SPSS Inc., Chicago, IL, USA) was used for analyzing the patient data. Data are presented as mean \pm standard deviation. The parametric independent samples *t*-test and the nonparametric Mann-Whitney *U*-test were used to compare differences between the two groups; the χ^2 test was used for categorical variables, and the Pearson correlation coefficient was used to analyze the relationship between the two groups. The level of statistical significance was set at a *P*-value <0.05 .

Results

The baseline characteristics as well as the results of the blood tests for the two groups are shown in Table 1. There were no significant differences in age, body mass index, blood glucose, white blood cell count, triglyceride and HDL-C between the two groups. However, there were statistically significant differences in the gender ratio (65.7% females in the vegetarian group vs 46.5% in the omnivore group, $P=0.007$), smoking rate (11.1 vs 22.2%, $P=0.036$), body

weight (58.66 \pm 11.13 vs 62.88 \pm 12.24 kg, $P=0.012$), body height (159.14 \pm 7.88 vs 162.53 \pm 8.14 cm, $P=0.003$), total cholesterol (184.74 \pm 33.23 vs 202.01 \pm 41.05 mg/dl, $P=0.001$), LDL-C (119.63 \pm 31.59 vs 135.89 \pm 39.50 mg/dl, $P=0.002$) and uric acid (5.05 \pm 1.44 vs 5.61 \pm 1.38 mg/dl, $P=0.006$). Table 1 also shows the important findings of the study; hs-CRP was significantly lower in vegetarians (0.14 \pm 0.23 mg/dl) than in omnivores (0.23 \pm 0.44 mg/dl, $P=0.025$), and homocysteine was significantly higher in vegetarians (10.97 \pm 6.69 μ mol/l) than in omnivores (8.44 \pm 2.50 μ mol/l, $P=0.001$).

There are statistically significant differences in homocysteine level between male and female subjects, in both vegetarian and omnivore groups as shown in Table 2. To eliminate the gender bias, we compared hs-CRP and homocysteine between vegetarian and omnivore males and vegetarian and omnivore females separately. Table 3a shows the results in males; there were no significant differences in the rate of smoking, body weight, body height and uric acid, but statistically significant differences remained in total cholesterol, LDL-C and homocysteine. Although the hs-CRP level showed a trend toward being lower in vegetarians than in omnivores for both males and females, the difference was not statistically significant. Table 3b shows the results in

Table 1 Baseline characteristics and results for all subjects

	Vegetarians Mean \pm s.d.	Omnivores Mean \pm s.d.	<i>P</i> -value
Age ^a (years)	51.24 \pm 8.88	49.38 \pm 9.60	0.159
Body weight ^a (kg)	58.66 \pm 11.13	62.88 \pm 12.24	0.012*
Body height ^a (cm)	159.14 \pm 7.88	162.53 \pm 8.14	0.003*
BMI ^a (kg/m ²)	22.9 \pm 2.81	23.79 \pm 3.56	0.082
Smoke ^b			
Yes	11 (11.1)	22 (22.2)	0.036*
No	88 (88.9)	77 (77.8)	
Gender ^b			
Male	34 (34.3)	53 (53.5)	0.007*
Female	65 (65.7)	46 (46.5)	
SBP ^a (mm Hg)	120.49 \pm 15.63	125.55 \pm 15.04	0.022*
DBP ^a (mm Hg)	75.01 \pm 11.90	78.76 \pm 11.71	0.027*
UA ^a (mg/dl)	5.05 \pm 1.44	5.61 \pm 1.38	0.006*
Cholesterol ^a (mg/dl)	184.74 \pm 33.23	202.01 \pm 41.05	0.001*
Triglyceride ^c (mg/dl)	95.93 \pm 65.53	102.71 \pm 78.94	0.590
HDL-C ^a (mg/dl)	56.16 \pm 15.20	55.62 \pm 14.50	0.796
LDL-C ^a (mg/dl)	119.63 \pm 31.59	135.89 \pm 39.50	0.002*
GLU ^a (mg/dl)	89.90 \pm 10.65	90.22 \pm 16.01	0.826
WBC ^a (10 ³ / μ l)	6.40 \pm 1.38	6.54 \pm 1.56	0.495
hs-CRP ^c (mg/dl)	0.14 \pm 0.23	0.23 \pm 0.44	0.025*
Homocysteine ^c (μ mol/l)	10.97 \pm 6.69	8.44 \pm 2.50	0.001*

* $P < 0.05$ statistical significance.

Abbreviations: BMI, body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure; UA, uric acid; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; WBC, white blood cell counts; hs-CRP, high-sensitivity C-reactive protein.

^aIndependent samples *t*-test.

^b χ^2 test.

^cMann-Whitney *U*-test.

females. As in males, there were no significant differences between vegetarian and omnivore females in body weight, body height and the rate of smoking. However, female vegetarians had significantly lower uric acid and total cholesterol levels, and significantly higher homocysteine levels. Although the LDL-C and hs-CRP levels showed a trend toward being lower in female vegetarians, the difference was not statistically significant.

No correlation was found between hs-CRP and homocysteine levels using log analysis with Pearson correlation (Table 4).

Discussion

A vegetarian diet has been well documented to reduce overall mortality, and especially cardiovascular and cancer

mortalities. It lowers serum cholesterol and LDL levels and hence reduces atherosclerosis. It lowers blood pressure and reduces the risk for type II diabetes. Vegetarians appeared to have a better risk factor profile.

Conventional cardiovascular risk factors

Our data show that Taiwanese vegetarians have a lower serum total cholesterol, LDL cholesterol, uric acid, and blood pressure as compared with Taiwanese omnivores. Other studies have also reported that vegetarians have a better lipid profile and lower blood pressure (Krajčovičová-Kudláčková *et al.*, 1994; Nagypová *et al.*, 1998). Lower levels of total cholesterol, LDL-C, and blood pressure have been shown to be cardioprotective and are consistent with the generally lower cardiovascular mortality seen in vegetarians (Klag *et al.*, 1993; Benetos *et al.*, 2003).

Table 2 Gender differences in homocysteine level

	Male, $\mu\text{mol/l}$ (N)	Female, $\mu\text{mol/l}$	P-value
Vegetarians (n=99)	15.00 \pm 9.74 (34)	8.86 \pm 2.55 (65)	<0.001
Omnivores (n=99)	9.82 \pm 2.40 (53)	6.85 \pm 1.46 (46)	0.011

Homocysteine levels were presented as mean \pm s.d.
 Statistic method: parametric independent samples t-test.

Table 3a Baseline characteristics and results for male and female subjects

	Vegetarians Mean \pm s.d.	Omnivores Mean \pm s.d.	P-value
Number	34	53	
Age ^a (years)	50.88 \pm 9.33	49.25 \pm 10.51	0.461
Body weight (kg) ^a	67.10 \pm 13.16	69.61 \pm 11.19	0.345
Body height (cm) ^a	166.68 \pm 7.13	167.75 \pm 5.96	0.448
BMI ^a (kg/m ²)	24.00 \pm 3.53	24.67 \pm 3.44	0.385
Smoke ^b			
Yes	11 (32.4)	21 (39.6)	0.493
No	23 (67.6)	32 (60.4)	
SBP ^a (mm Hg)	123.15 \pm 16.30	126.89 \pm 15.23	0.288
DBP ^a (mm Hg)	79.71 \pm 9.67	81.43 \pm 12.03	0.462
UA ^a (mg/dl)	6.42 \pm 1.23	6.22 \pm 1.35	0.471
Cholesterol ^a (mg/dl)	183.85 \pm 33.63	201.36 \pm 37.28	0.029*
Triglyceride ^c (mg/dl)	127.62 \pm 87.46	127.00 \pm 97.8	0.744
HDL-C ^a (mg/dl)	47.97 \pm 17.52	49.32 \pm 11.86	0.669
LDL-C ^a (mg/dl)	120.44 \pm 28.94	138.98 \pm 35.74	0.013*
Glucose ^a (mg/dl)	90.09 \pm 7.60	91.53 \pm 20.73	0.647
WBC ^a (10 ³ / μ l)	6.73 \pm 1.35	6.75 \pm 1.59	0.941
hs-CRP ^c (mg/dl)	0.12 \pm 0.18 ^a	0.24 \pm 0.43	0.087
Homocysteine ^c ($\mu\text{mol/l}$)	15.00 \pm 9.74	9.82 \pm 2.40	0.001*

^aIndependent samples t-test.

^b χ^2 test.

^cMann-Whitney U-test.

*P<0.05 statistical significance.

Abbreviations: BMI, body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure; UA, uric acid; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; WBC, white blood cell counts; hs-CRP, high-sensitivity C-reactive protein.

Table 3b Baseline characteristics and results for female subjects

Female	Vegetarians Mean \pm s.d.	Omnivores Mean \pm s.d.	P-value
Number	65	46	
Age ^a (years)	51.43 \pm 8.71	49.54 \pm 8.54	0.259
Body weight ^a (kg)	54.24 \pm 6.52	55.13 \pm 8.16	0.525
Body height ^a (cm)	155.20 \pm 4.79	156.50 \pm 5.84	0.201
BMI ^a (kg/m ²)	22.47 \pm 2.21	22.78 \pm 3.46	0.591
Smoke ^b			
Yes	0 (0.0)	1 (2.2)	0.232
No	65 (100)	45 (97.8)	
SBP ^a (mm Hg)	119.11 \pm 15.22	124.00 \pm 14.84	0.094
DBP ^a (mm Hg)	72.55 \pm 12.28	75.67 \pm 10.65	0.157
UA ^a (mg/dl)	4.34 \pm 0.94	4.92 \pm 1.06	0.003*
Cholesterol ^a (mg/dl)	185.20 \pm 33.28	202.76 \pm 45.42	0.020*
Triglyceride ^c (mg/dl)	79.35 \pm 42.65	74.72 \pm 34.43	0.806
HDL-C ^a (mg/dl)	60.45 \pm 11.89	62.87 \pm 13.97	0.328
LDL-C ^a (mg/dl)	119.2 \pm 33.1	132.33 \pm 43.57	0.074
GLU ^a (mg/dl)	89.65 \pm 11.99	88.72 \pm 7.58	0.619
WBC ^a (10 ³ / μ l)	6.22 \pm 1.37	6.30 \pm 1.50	0.799
hs-CRP ^c (mg/dl)	0.14 \pm 0.25	0.22 \pm 0.45	0.220
Homocysteine ^c ($\mu\text{mol/l}$)	8.86 \pm 2.55	6.85 \pm 1.46	<0.001*

^aIndependent samples t-test.

^b χ^2 test.

^cMann-Whitney U-test.

*P<0.05 statistical significance.

Abbreviations: BMI, body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure; UA, uric acid; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; WBC, white blood cell counts; hs-CRP, high-sensitivity C-reactive protein.

Table 4 Correlations between hs-CRP and homocysteine

	Log(hs-CRP)
Log(homocysteine) (N)	198
Pearson correlation coefficient	-0.012
P-value	0.865

High-sensitivity C-reactive protein

Given that atherosclerosis is an inflammatory disease (Danesh *et al.*, 1998), hs-CRP is considered to be a good prognostic indicator of long-term cardiovascular and cerebrovascular events. Overall, our data showed a similar result, in that the serum hs-CRP level was significantly lower in vegetarians than in omnivores as a group; however, only a non-significant trend was seen when males and females were compared separately probably because of the small sample size. Szeto *et al.* (2004) found that a long-term Chinese (Hong Kong) vegetarian diet, which was likely similar to the Taiwanese vegetarian diet, is associated with lower hs-CRP levels and a better antioxidant status. The relatively lower hs-CRP level in our study implies that Taiwanese vegetarians have a lower inflammation status, which reflects a lower cardiovascular risk.

Homocysteine

Our data demonstrated that homocysteine level is significantly higher in males than in females in both the vegetarian and the omnivore groups. This is consistent with studies of healthy population (Lim and Heo, 2002; Chang *et al.*, 2003; Fakhrzadeh *et al.*, 2006; Taskin *et al.*, 2006). Higher homocysteine concentrations in men than in women may be explained by differences in muscle mass, hormone and vitamin status (Refsum *et al.*, 2006). Our data also showed that the vegetarians had a significantly higher level of homocysteine than omnivores in both men and women. This result is similar to that of previous studies on vegetarians carried out in Taiwan and elsewhere (Kraječovičová-Kudláčková *et al.*, 2000; Hung *et al.*, 2002; Herrmann *et al.*, 2003; Huang *et al.*, 2003; Su *et al.*, 2006). In experimental studies, homocysteine has been shown to stimulate vascular smooth muscle cells to proliferate and to synthesize collagen, which is a hallmark of atherogenesis. Homocysteine also adversely affects the anticoagulant systems that are mediated by the vascular endothelium (Harpel, 1997). A recent meta-analysis of prospective and retrospective studies dealing with homocysteine suggested that an elevated homocysteine level is a modest independent predictor of ischemic heart disease and stroke risk in a healthy population (The Homocysteine Studies Collaboration, 2002). In a recent study of 118 postmenopausal Taiwanese women (57 vegetarians and 61 omnivores), fasting blood glucose, LDL-C and vitamin B₁₂ were significantly lower, whereas homocysteine and soluble vascular cell adhesion molecule-1 (sVCAM-1) were significantly higher in vegetarians than in omnivores. However, no significant difference in carotid atherosclerosis, as measured by ultrasound, was found between these two groups (Su *et al.*, 2006). This implies that even with the higher homocysteine levels found in vegetarians, the carotid artery intima-media thickness and extracranial carotid artery plaque score of vegetarians were, at least, not worse than in omnivores. In our study, the lower blood pressure, better lipid profile and lower hs-CRP are

cardioprotective, whereas the elevated homocysteine level is a predictor of long-term cardiovascular events. We also found that there was no correlation between the hs-CRP and homocysteine levels. This implies that hyperhomocysteinemia is not associated with high hs-CRP levels in Taiwanese vegetarians.

Predictive value of different risk factors

It appeared that homocysteine is only one of the risk factors predisposing to atherosclerosis, whereas the hs-CRP level represents the overall vascular inflammation status, which implies the presence of vascular damage, and is thus a direct sign of cardiovascular disease. Thus, the hs-CRP level is not only a mediator of atherothrombosis but also a marker for cardiovascular disease (Jialal *et al.*, 2004).

In a prospective case-control study of 28 263 healthy postmenopausal women over 3 years, Ridker *et al.* (2000) demonstrated that hs-CRP was the strongest univariate predictor of the risk of cardiovascular events (relative risk 4.4), followed by the ratio of total cholesterol to HDL-C (relative risk 3.4), total cholesterol (relative risk 2.4), LDL cholesterol (relative risk 2.4), and homocysteine (relative risk 2.0). This would suggest that Taiwanese vegetarian diets offer cardiovascular protection if we judge the total cardiovascular risk profiles. Although we do not have long-term morbidity/mortality data, Taiwanese vegetarian diet has been reported to improve insulin sensitivity (Kuo *et al.*, 2004) and vascular dilatory and endothelial functions (Lin *et al.*, 2001).

Vitamin supplementation

German vegetarians, especially vegans, have been found to have hyperhomocysteinemia, which has been attributed to functional vitamin B₁₂ deficiency (Herrmann *et al.*, 2003). In Taiwanese vegetarians, the intake and mean plasma concentration of vitamin B₁₂ were lower than in omnivores, which leads to an increase in plasma homocysteine concentration. Furthermore, vitamin B₆ and folate have little effect on plasma homocysteine concentration when individuals have an adequate vitamin B₆ and folate status (Huang *et al.*, 2003). In The Swiss Heart Study, homocysteine-lowering therapy with folic acid, vitamin B₁₂ and vitamin B₆ significantly decreases the incidence of major events after percutaneous coronary intervention (Schnyder *et al.*, 2002). Even though Taiwanese vegetarians were found to have higher plasma homocysteine levels than omnivores (8.44 vs 10.97 $\mu\text{mol/l}$), they are still way below the hyperhomocysteinemia (level of homocysteine > 14 $\mu\text{mol/l}$), whether dietary supplementation with vitamin B₁₂ would lower homocysteine levels and have additional benefits on top of the cardiovascular protective effects of vegetarian diets, remains to be studied.

Conclusion

Taiwanese vegetarian diet has been reported to improve insulin sensitivity and vascular dilatory and endothelial

functions: As the pathogenesis of atherosclerosis is a complex process, the cardiovascular protective effects of a vegetarian diet are multifactorial. Thus, the risk factors should be judged in aggregate, rather than singly. In this study, we found that Taiwanese vegetarians had a lower hs-CRP level, lower blood pressure, lower total cholesterol and lower LDL-C than omnivores. However, homocysteine levels were higher in vegetarians. Owing to different predictive value of each risk factor, we believe the Taiwanese vegetarians had a better cardiovascular risk profile than omnivores. However, whether the Taiwanese vegetarian diets should be supplemented with vitamin B₁₂ to lower serum homocysteine levels remains to be addressed. Further studies, especially long-term follow-up data to develop CHD risk prediction algorithms suited for Taiwanese population, are needed.

Acknowledgements

The present study was supported by grant DTCRD 93(2)-08 from The Buddhist Dalin Tzu Chi General Hospital, Chia-Yi, Taiwan, Republic of China.

The authors are grateful for the statistical assistance of Jing-Er Chou, PhD of the National Yunlin University of Science and Technology.

Conflicts of interest

We declare that we have no conflict of interest.

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