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A bean-free diet increases the risk of all-cause mortality among Taiwanese women: the role of the metabolic syndrome

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Abstract

Objective: To evaluate the associations with chronic disease risk and mortality of the consequences of bean-free diets in Taiwanese adults with regard to gender.
Design: A sub-sample of the National Health Interview Survey (NHIS) in 2001 agreed to physical examination in the subsequent year. This group then took part in the Taiwanese Survey of Hyperglycaemia, Hyperlipidaemia and Hypertension (TwSHHH) in 2002.
Setting: Individual records were linked to the eventual death files from 2002 to 2008.
Subjects: Up to the end of 2008, a total of 2820 men and 2950 women were tracked by death registry over the 6·8 years of follow-up.
Results: Among 38 077 person-years, an average follow-up 6·5 years, 225 all-cause deaths were identified. Generalized linear models showed beans to be favourable for metabolic syndrome (other than for fasting glucose) in men; in women, beans were favourable for waist circumference and HbA1c. Cumulative logistic regression models for the effect of a bean-free diet on metabolic syndrome scores according to the Taiwanese-modified National Cholesterol Education Program–Adult Treatment Panel III (NCEP-tw) gave adjusted odds ratios of 1·83 in men and 1·45 in women. Cox regression models for the bean-free diet showed an increased hazard ratio for all-cause mortality among women (1·98, 95 % CI 1·03, 3·81) but not men (1·28, 95 % CI 0·76, 2·16).
Conclusions: A bean-free diet may play a role in developing the metabolic syndrome in both genders, and is a significant predictor of all-cause mortality in Taiwanese women but not men.

Keywords
Legumes
Green vegetables
Fat
Population-attributable risk
Beans

Beans, which are among the longest of cultivated foods, have many nutritional properties – by way of macronutrients, micronutrients and other bioactive components – and have distinctive physico-chemical characteristics. They have a particular place in Chinese culinary and medical culture. The Chinese *Compendium of Materia Medica* (*Běncǎo Gāngmù*), a pharmaceutical text written by the naturalist and medical observer Li Shizhen (1518–1593) during China's Ming dynasty, identified a number of medical applications for beans. Li asserted that beans of five colours were required for a comprehensive approach to disease. For example, he described how consumption of black beans could benefit muscle and skin health, colour and complexion, bone marrow, appetite and vitality. He reported that the Chinese Han dynasty emperor Liu An (179–122 BC) prepared bean curd from many types of bean[1].

In 1990, Wilcox *et al.*[2] demonstrated that soyabeans could partially restore oestrogenic activity in postmenopausal women. Since then, various clinical trials have examined the beneficial effects of isoflavones or phyto-oestrogens on body fat and its distribution, serum glucose, insulin and lipid metabolism, especially in postmenopausal women[3]. Epidemiological studies have supported the benefits of soya or isoflavones on human physiology and metabolism[3,4], the contribution of legumes to the reduction of age-related disorders, such as skin wrinkling and some diseases[5], hormone-dependent cancers (breast cancer and prostate cancer) and other cancers[6,7]. Few studies have focused on the longevity that might be associated with the dietary intake of legumes or beans, although those that have had favoured North-East Asia, Australia, the Mediterranean and Scandinavia[8–11]. The present study evaluates the extent to which bean-free diets

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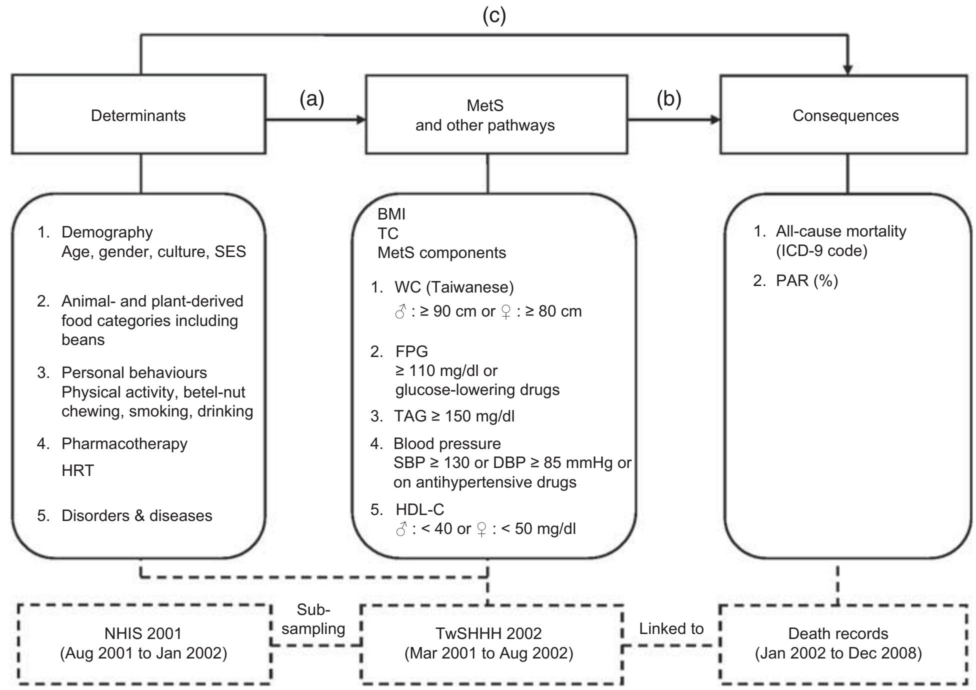

Fig. 1 The conceptual framework for the associations between beans as part of food intake, the metabolic syndrome (MetS) and mortality in Taiwanese adults. Cross-sectional analyses are indicated by (a) and longitudinal analyses by (b) and (c). SES, socio-economic status; HRT, hormone replacement therapy; TC, total cholesterol; ♂, males; ♀, females; WC, waist circumference; FPG, fasting plasma glucose; SBP, systolic blood pressure; DBP, diastolic blood pressure; HDL-C, HDL cholesterol; ICD-9, International Classification of Diseases, ninth revision; PAR, population-attributable risk; NHIS, National Health Interview Survey; TwSHHH, Taiwanese Survey of Hyperglycaemia, Hyperlipidaemia and Hypertension

in a soya-oriented food culture like that of Taiwan modify chronic disease risk and examines the consequences of such diets on mortality, with particular regard to gender. The conceptual framework within which we introduce the notion that a diet without beans may determine mortality and its population-attributable risk with or without the metabolic syndrome is shown in Fig. 1.

Materials and methods

Study population

The National Health Interview Survey (NHIS) 2001 in Taiwan, a multistage stratified systematic sample to explore utilization of medical care, health status and medical costs, based on registered residents at the end of 2000, was used[12]. During August 2001 to January 2002, members of four households aged 15 years or older were randomly sampled from each selected smallest administrative unit, *lin*, and invited to be interviewed, giving a total of 6592 households and 26 685 participants aged 15 years or above among the 1628 selected *lin*. All enrolees provided informed consent and the study gained ethics approval by the National Health Research Institutes' Institutional Review Board. Of the NHIS 2001 households studied, half of those in the *lin* in Taipei area and all of those in the *lin* in half of the NHIS 2001 townships in the rest of Taiwan had physical measurements and fasting venepuncture samples for a range of analytes. These observations were made from March to August 2002, as part of the TwSHHH (Taiwan Survey for Hypertension, Hyperglycemia, and Hyperlipidemia) 2002, based on a sub-sample of NHIS 2001. Among a representative list of 10 292 NHIS individuals (≥15 years) in 2001 from 3296 households in 824 townships, a total of 9943 people with confirmed address and telephone number were eligible for TwSHHH 2002. On the grounds of institutionalization, 590 persons were excluded. A further 1775 individuals declined to be interviewed. Thus, there were 7578 eligible persons who responded to the questionnaire. Of the 7578 individuals, 6941 participants had blood pressure measurements (637 refusals) and 6602 persons had blood taken (976 refusals) in the TwSHHH 2002. In all, 6600 persons completed the three requirements; 5786 participants were successfully linked with their NHIS 2001 database, and these comprised 2827 men and 2959 women who could be followed with regard to mortality.

Demography, diet history and health behaviours interview

The NHIS 2001 structured questionnaire included demographic information, health status, utilization of medical resources, health-related behavior and health awareness. For the purposes of the present study, no distinction was made on the basis of ethnicity. Socio-economic status (SES) was categorized by a two-factor index of social position: SES score = 4 × (Education index) + 7 × (Job index)[13].

The cut-off points of SES score for low, middle and high levels were defined as 11–29, 30–40 and 41–55, respectively. A self-administered simplified FFQ of twenty items in NHIS 2001 was used to assess the intake frequency for 1 week, or in the case of grains for 1 d, and included meat, fish, seafood, eggs, milk, cheese, yoghurt, beans, vegetables, fruit, hamburgers, fries, pizza, cookies/candies/chocolates, cake/bread, cola/root beer, ice cream/milkshakes, coffee/tea, sugary drinks and grains. Response categories for food frequency were never, <1, 1–2, 3–5 or >5 times/week, except that the last item was recorded as bowls/d.

Information about personal behaviours was quantified as follows: alcohol drinking status (current drinkers *v.* current non-drinkers), smoking habits (current smokers $\geq$100 lifetime cigarettes or not), betel-nut chewing status (current chewers or not) in the past week, and physical activity ($\geq$10 MET (metabolic equivalent task) or not) calculated for the frequency and total time taken during the past 2 weeks. The use of hormone replacement therapy (HRT) for the menopausal syndrome was gathered from women (‘never user’, ‘ex-user’ and ‘current user’). TwSHHH 2002 collected additional information about food preparation methods and eating habits. It was recorded as always, often, sometimes, seldom, never or not eating this food. This provided data on fat intake by way of food habits in eating fat, such as ‘ meat with fat’, ‘poultry with skin’, ‘egg with yolk’ and cooking technique such as ‘fried meat’, ‘fried fish’ and ‘fried egg’. Specific questions were asked, for example, about the frequency of consumption of dark-green vegetables at lunch and dinner. All missing data were considered as an additional category.

Physical examinations

In NHIS 2001, height and weight were reported by the interviewees. BMI was calculated[14]. In TwSHHH 2002, the physical examination included waist circumference (WC), hip circumference (HC) and blood pressure (BP)[15]. The waist-to-hip ratio (WHR) was calculated from the ratio of the circumference of the waist to that of the hips. After sitting at rest for at least 5 min, BP was measured twice at a 5 min interval. Systolic blood pressure (SBP) and diastolic blood pressure (DBP) were taken as the first appearance and the complete disappearance of sound with a standard mercury sphygmomanometer (mmHg). A third measurement was required where the difference between two repeats reached 10 mmHg or more. The mean of these BP measurements was used.

Medical history and blood analytes

In TwSHHH 2002, household interviews were conducted by a trained nurse. These provided a medical, accidental and pharmaceutical history, as well as a family history for first-degree relatives. Venous blood was collected after a 12 h fast, and stored at -20°C to -40°C until analysis. Analytes were measured by standard clinical chemistry methods subject to international quality control. These included fasting plasma glucose (FPG), TAG, total cholesterol (TC), high-HDL cholesterol (HDL-C), blood urea nitrogen (BUN), creatinine, uric acid (UA), serum glutamic pyruvic transaminase (GPT), serum glutamic oxaloacetic transaminase (GOT) and glycated Hb (HbA1c). LDL cholesterol (LDL-C) was estimated by the formula LDL-C = TC – (TAG/5 + HDL-C). Apo A1 and apo B were measured by immunoturbidimetry.

Outcome measures

Across all cities and counties, official death certificates were established and released officially by the Department of Health, Executive Yuan, Taiwan, where causes of death are defined by the International Classification of Diseases, ninth revision (ICD-9). Individual records were linked to these eventual death files from 2002 to 2008.

Statistical analyses

For all statistical analyses, the SAS statistical software package version 9·1 (SAS Institute, Cary, NC, USA) was used and significance levels were set at $\alpha = 0{\cdot}05$. Frequency of bean consumption was divided into five categories, with means and standard deviations for sociodemographic, clinical characteristics, metabolic syndrome (MetS) and its scores based on the NCEP-tw criteria (the modified criteria of the National Cholesterol Education Program–Adult Treatment Panel III in Taiwan)[16]. NCEP-tw MetS was defined as individuals having three or more of the following five criteria: (i) Taiwanese males WC $\geq$ 90 cm, Taiwanese females WC $\geq$ 80 cm; (ii) FPG $\geq$ 110 mg/dl or on glucose-lowering medication; (iii) fasting TAG $\geq$ 150 mg/dl; (iv) SBP $\geq$ 130 mmHg or DBP $\geq$ 85 mmHg or on antihypertensive medication; (v) males HDL-C $<$ 40 mg/dl, females HDL-C $<$ 50 mg/dl. NCEP-tw MetS scores are a summation of the above five criteria. By modifying the NCEP-tw MetS, the form of IER MetS comprising IER (impaired energy regulation), which has been referred to as its energy regulation core of FPG, TAG and WC[16], was obtained. Generalized linear models, adjusted for age, were used to test least-square means between participants with a bean-free diet (0 times/week) and those with a bean diet (<1, 1–2, 3–5, >5 times/week) through the coefficient set of linear combinations as (-1, 0·25, 0·25, 0·25, 0·25). This was designed to reduce the diversity of sample sizes among the five groups and signified the contrast of means between participants with a bean-free diet and those without. The distributions of categorical variables were assessed for the existence of a linear trend in proportions by the χ^2 test for trend.

Based on the baseline data set, cumulative logistic regression analyses were used to explore the cross-sectional effects of risk factors and (six) ordinal responses in NCEP-tw MetS scores 0–5[17]. For each gender, adjusted OR and the corresponding 95 % CI were calculated for each predictor by mutually controlling for other variables. Each OR was estimated to make a common explanation of all (five) possible combinations of higher *v.* lower MetS score category (MetS score 'k or higher' against 'less than k', where $k = 1, 2, 3, 4, 5$). After linkage to the follow-up data set, Cox proportional hazard models were applied to estimate the long-term effect of baseline measurements on the multivariate-adjusted hazard ratios (HR) of all-cause mortality and their 95 % CI. The population-attributable risk (PAR, %) was used to estimate the reduced risk proportion attributed to the removal of the specific risk factor. The PAR was formulated as $P_e \times (HR - 1)/HR$, where P_e denotes the proportion of all-cause deaths attributable to the specific risk factor among total all-cause deaths[18]. Baseline variables were adjusted in the cumulative logistic regressions and Cox proportional hazard models. They included age (in 10-year increments), socio-economic status (low, middle, high), meat intake, fish/seafood intake, dairy products intake, grain intake ≥3 bowls/d, dark-green vegetables intake, fruit intake >5 times/week, iced food/sweetened soft drinks/cola, baked products/sweets/chocolate, high fat intake, coffee or tea intake, current alcohol drinker, current smoker ≥100 lifetime cigarettes, current betel-nut chewer, physical activity (per 10 MET-h/week) and history of HRT. We further considered the situation where the BMI variable could not satisfy the proportional hazard assumption in Cox models and where it may have a J-shape, U-shape or negative relationship, as exemplified in other types of association with all-cause mortality[19–21]. Stratified Cox models were used to control BMI variable (<18·5, 18·5–22·9, 23·0–24·9, 25·0–29·9, ≥30·0 kg/m^2) based on the International Obesity Taskforce Asia Pacific BMI classifications[22], stratified as underweight, normal weight, overweight, obese class I and obese class II. Each BMI stratum had a distinct baseline hazard function but common values for coefficients of other covariates.

Results

Tables 1 and 2, together with Figs 2 and 3, show the baseline characteristics of participants in the five categories

Table 1 Baseline characteristics of 2820 men, categorized by frequency of bean intake in NHIS 2001 and TwSHHH 2002, Taiwan

	Frequency of bean intake										
	0 times/week (*n* 151)		<1 time/week (*n* 412)		1–2 times/week (*n* 838)		3–5 times/week (*n* 873)		>5 times/week (*n* 546)		
Variable	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	*P* value
Age (years)	52·1	17·6	43·9	16·6	43·3	16·2	41·4	15·8	42·5	15·4	<0·0001*
	%		%		%		%		%		
Education											<0·0001*
Junior high school and below	32·5		25·5		22·8		17·8		17·6		
Senior high school	23·8		21·1		18·4		16·7		19·0		
College and above	43·7		53·4		58·8		65·5		63·4		
Socio-economic status											<0·0001*
Low	71·3		56·7		51·7		48·0		49·0		
Middle	14·7		14·4		14·4		17·2		17·1		
High	14·0		29·0		33·9		34·9		33·9		
Exercise ≥10 MET-h/week	25·2		35·2		33·7		34·7		34·4		0·2273
Current drinker	37·8		45·2		43·4		44·1		40·3		0·6663
Current smoker ≥100 lifetime cigarettes	56·3		50·7		47·6		47·5		47·6		0·0862
Current betel-nut chewer	19·9		19·2		17·8		16·7		15·4		0·0645
IER MetS score†											0·0001*
0	35·8		50·0		53·0		53·6		50·9		
1	29·8		27·2		29·8		29·3		30·8		
2	25·8		18·2		14·2		14·7		15·9		
3	8·6		4·6		3·0		2·4		2·4		
NCEP-tw MetS score											<0·0001*
0	19·2		35·9		37·5		38·5		38·3		
1	23·2		25·7		29·0		25·9		24·0		
2	21·9		15·8		17·9		20·3		21·8		
3	23·8		14·3		9·6		10·3		9·9		
4	8·0		5·3		4·8		4·2		5·1		
5	4·0		2·9		1·3		0·8		0·9		
IER MetS†	34·4		22·8		17·2		17·1		18·3		<0·0001*
NCEP-tw MetS	35·8		22·6		15·6		15·3		15·9		<0·0001*

NHIS, National Health Interview Survey; TwSHHH, Taiwanese Survey of Hyperglycaemia, Hyperlipidaemia and Hypertension; MET, metabolic equivalent task; IER, impaired energy regulation; MetS, metabolic syndrome; NCEP-tw, Taiwanese-modified National Cholesterol Education Program–Adult Treatment Panel III.
*$P < 0·05$; generalized linear models were used to test least-square means between participants' age variable with bean-free diet (0 time/week) and with bean diet (<1, 1–2, 3–5, >5 times/week) through the coefficient set of linear combinations as (−1, 0·25, 0·25, 0·25, 0·25); the χ^2 test was applied to test the trend of proportions across frequency of bean intake.
†IER MetS score: IER comprises waist circumference (WC), fasting plasma glucose (FPG) and TAG[16]. IER MetS score is counted by the summation of the following three criteria: (i) Taiwanese males WC ≥ 90 cm; Taiwanese females WC ≥ 80 cm; (ii) FPG ≥ 110 mg/dl or on glucose-lowering medication; (iii) fasting TAG ≥ 150 mg/dl. IER MetS represents an individual whose IER MetS score is ≥2.

Table 2 Baseline characteristics of 2950 women, categorized by frequency of bean intake in NHIS 2001 and TwSHHH 2002, Taiwan

	Frequency of bean intake										
	0 times/week (*n* 139)		<1 time/week (*n* 466)		1–2 times/week (*n* 922)		3–5 times/week (*n* 838)		>5 times/week (*n* 585)		
Variables	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	*P* value
Age (years)	45·2	17·5	42·7	15·4	41·0	14·8	41·6	14·4	42·5	15·4	0·0147*
	%		%		%		%		%		
Education											0·0003*
Junior high school and below	42·5		32·8		27·3		25·9		27·9		
Senior high school	20·2		16·0		16·5		15·8		16·4		
College and above	37·4		51·3		56·2		58·4		55·7		
Socio-economic status											<0·0001*
Low	75·4		69·9		64·4		61·5		61·1		
Middle	14·2		12·6		15·5		16·2		14·5		
High	10·5		17·5		20·0		22·3		24·4		
Exercise ≥10 MET-h/week	28·8		30·5		30·4		30·9		36·6		0·0222*
Current drinker	14·4		12·5		11·5		10·1		8·9		0·0134*
Current smoker ≥100 lifetime cigarettes	5·8		6·4		2·6		3·0		3·3		0·0116*
Current betel-nut chewer	0·7		1·5		1·0		2·3		0·9		0·7312
History of HRT use	10·8		9·7		7·6		7·5		7·5		0·1203
IER MetS score†											0·0018*
0	51·1		60·7		65·1		62·9		65·5		
1	27·3		22·3		22·8		23·5		22·1		
2	15·1		14·2		9·7		11·0		9·2		
3	6·5		2·8		2·4		2·6		2·2		
NCEP-tw MetS score											0·0137
0	33·8		45·1		48·4		47·1		46·5		
1	30·2		25·5		26·1		27·8		28·4		
2	15·8		15·7		15·4		12·4		14·2		
3	10·1		9·0		5·6		9·3		6·0		
4	7·2		4·1		3·7		2·6		3·6		
5	2·9		0·6		0·8		0·7		1·4		
IER MetS†	21·6		17·0		12·2		13·6		11·5		0·0023*
NCEP-tw MetS	20·1		13·7		10·1		12·6		10·9		0·0528

NHIS, National Health Interview Survey; TwSHHH, Taiwanese Survey of Hyperglycaemia, Hyperlipidaemia and Hypertension; MET, metabolic equivalent task; IER, impaired energy regulation; MetS, metabolic syndrome; NCEP-tw, Taiwanese modified National Cholesterol Education Program–Adult Treatment Panel III.
*$P < 0·05$, generalized linear models were used to test least-square means between participants' age variable with bean-free diet (0 time/week) and with bean diet (<1, 1–2, 3–5, >5 times/week) through the coefficient set of linear combinations as (−1, 0·25, 0·25, 0·25, 0·25); the χ^2 test was applied to test the trend of proportions across frequency of bean intake.
†IER MetS score: IER comprises waist circumference (WC), fasting plasma glucose (FPG) and TAG[16]. IER MetS score is counted by the summation of the following three criteria: (i) Taiwanese males WC ≥ 90 cm; Taiwanese females WC ≥ 80 cm; (ii) FPG ≥ 110 mg/dl or on glucose-lowering medication; (iii) fasting TAG ≥ 150 mg/dl. IER MetS represents an individual whose IER MetS score is ≥2.

of bean consumption frequency for Taiwanese men and women, respectively. There were 2820 (out of 2827) men and 2950 (out of 2959) women aged 17 to 93 years, excluding eight missing observations for bean intakes and eight mismatched ID linkages to death certificates. For men, those whose diet was more bean-free were elderly; had lower HDL-C; had higher BMI, WC, HC, SBP, DBP, TC, TAG, LDL-C, apo B and serum GOT; had higher IER MetS and NCEP-tw MetS scores; were less educated; and had lower SES. For female participants with a bean-free diet, they were aged, less educated and had a lower level of SES, and had higher values for WC, WHR, SBP, HbA1c, LDL-C, apo B, UA, serum GOT, IER MetS score and NCEP-tw MetS score.

Figures 2 and 3 allow comparison of the physical and analyte measurements, respectively, across the five categories of bean intake frequency in men (black lines) and women (grey lines). Compared with women, men had higher BMI, WC and WHR, as well as SBP and DBP. For analytes men had more abnormal lipid (TAG, LDL-C, HDL-C, apo B and apo A1), glycaemic (FPG and HbA1c) and hepatic function (GOT and GPT) and renal (BUN) and UA status than women. Men who ate more beans had more favourable lipid, hepatic, renal function and UA profiles. Women who ate more beans had more favourable glycaemic and hepatic function status.

Table 3 shows the risk as OR and HR by dietary pattern and gender for the NCEP-tw MetS score (0–5 points) in NHIS 2001 and TwSHHH 2002, and all-cause mortality over the period 2002–2008. It demonstrates that men (OR = 1·83) and women (OR = 1·45) would be more likely to have higher NCEP-tw MetS scores if they do not eat beans. During 38 077 person-years of follow-up, a mean of 6·5 years, 225 all-cause deaths were recorded, which included 204 natural deaths, thirteen accidents, six deaths from suicide and two deaths from unknown causes. The top twelve causes of death were listed as follows: eighty-two deaths from cancer (ICD-9 code: 140–239,

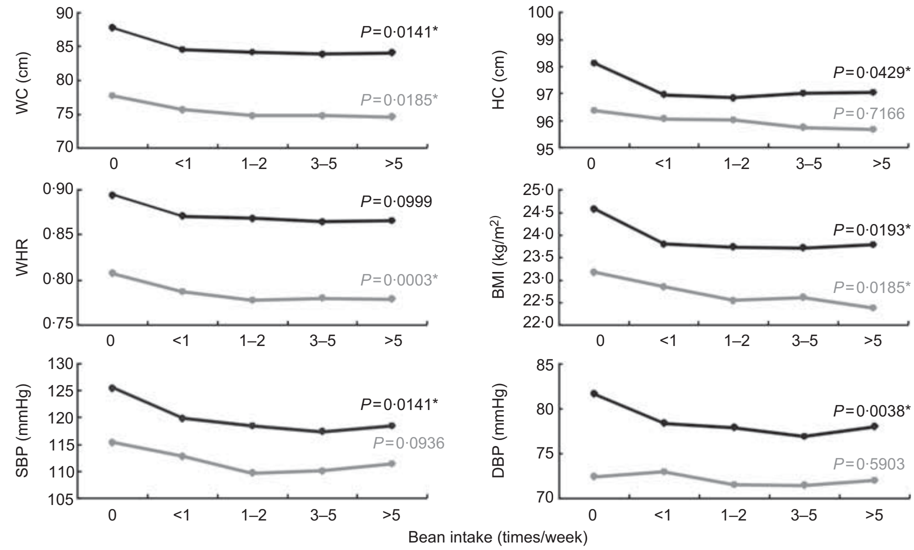

Fig. 2 Patterns of anthropometry (WC, waist circumference; HC, hip circumference; WHR, waist-to-hip ratio) and blood pressure (SBP, systolic blood pressure; DBP, diastolic blood pressure) across bean intake frequencies by gender (—, men; —, women) in Taiwanese adults. *$P < 0{\cdot}05$; generalized linear models adjusting for age were used to test least-square means between participants with a bean-free diet (0 times/week) and those with a bean diet (<1, 1–2, 3–5, >5 times/week) through the coefficient set of linear combinations as (−1, 0·25, 0·25, 0·25, 0·25)

36·4 % of all causes), twenty-three from stroke (430–438, 10·2 %), twenty-one from injury and poisoning (800–999, 9·3 %), fifteen from digestive system disease (570–578, 6·7 %), thirteen from diabetes mellitus (250, 5·7 %), thirteen from symptoms, signs and ill-defined conditions (780–799, 5·7 %), eleven from unspecified pneumonia (486, 4·8 %), nine from CHD (410–414, 4·0 %), seven from other forms of heart disease (420–429, 3·1 %), six from chronic obstructive pulmonary disease (490–496, 2·6 %), six from genitourinary diseases (580–629, 2·6 %) and five from hypertensive disease (401–405, 2·2 %). Among thirty female cancer deaths, thirteen cases were 'oestrogen-related' cancer, including breast (174, nine cases), cervical (180, three cases) and ovarian cancer (183, one case), while the leading cause of cancer death was lung cancer (162, fifteen cases) among fifty-two male cancers.

In model 1 of Table 3, a bean-free diet increased all-cause mortality significantly in women (HR = 1·98, 95 % CI 1·03, 3·81), but not in men (HR = 1·28, 95 % CI 0·76, 2·16). The NCEP-tw MetS significantly predicted mortality in women (HR = 1·75, 95 % CI 1·07, 2·84), but did not do so in men (HR = 1·19, 95 % CI 0·83, 1·72). Replacing NCEP-tw MetS with IER MetS in these models, the IER MetS was not a significant predictor for female (HR = 1·37, 95 % CI 0·84, 2·24) or male mortality (HR = 1·07, 95 % CI 0·73, 1·55; not shown). For the assessment of PAR in women, not having a bean intake accounted for 7·33 % of all-cause mortality; for men it was 2·73 %, although the HR was not significant for men. With regard to the NCEP-tw MetS, this predictor had a PAR of 18·99 % in women, but 4·96 % in men. Compared with the results of Cox model 1, regardless of male or female mortality, stratified Cox model 2 had similar effects of a bean-free diet. Enhanced effects of NCEP-tw MetS for women were found in model 2 (HR = 1·97, 95 % CI 1·18, 3·30). Especially, NCEP-tw MetS became a significant predictor for male mortality in model 2 (HR = 1·59, 95 % CI 1·05, 2·38). In addition, low TC (<200 mg/dl) then increased mortality in males (HR = 1·65, 95 % CI 1·11, 2·46), but not in females. This HR (1·65) and the high proportion (77·08 % of death cases attributable to having low TC) involved the male mortality PAR of 30·45 %. Through BMI stratifications and TC adjustment, the PAR of NCEP-tw MetS for men was strengthened in model 2 (11·28 %).

Discussion

A conceptual framework for the possible links between food intake, the MetS and mortality in Taiwanese adults is presented in Fig. 1. On this basis, the associations we consider in the present study are (i) how a bean-free diet may account for MetS with a score from 0 to 5; and (ii) what longitudinal impact a bean-free diet might have on all-cause mortality with MetS (yes *v.* no), or its components, as a potential modifier (in Table 3).

Beans, variously referred in the English language as legumes and pulses, and which include lentils and peas, have a complex food chemistry. In the case of soya, this may be as drinks; through processing as soya flour, tofu, various components or isolates; or following fermentation, such as with tempeh, natto, bean cake and sweet black soyabean. Components of particular relevance to the protection against MetS include dietary fibre and

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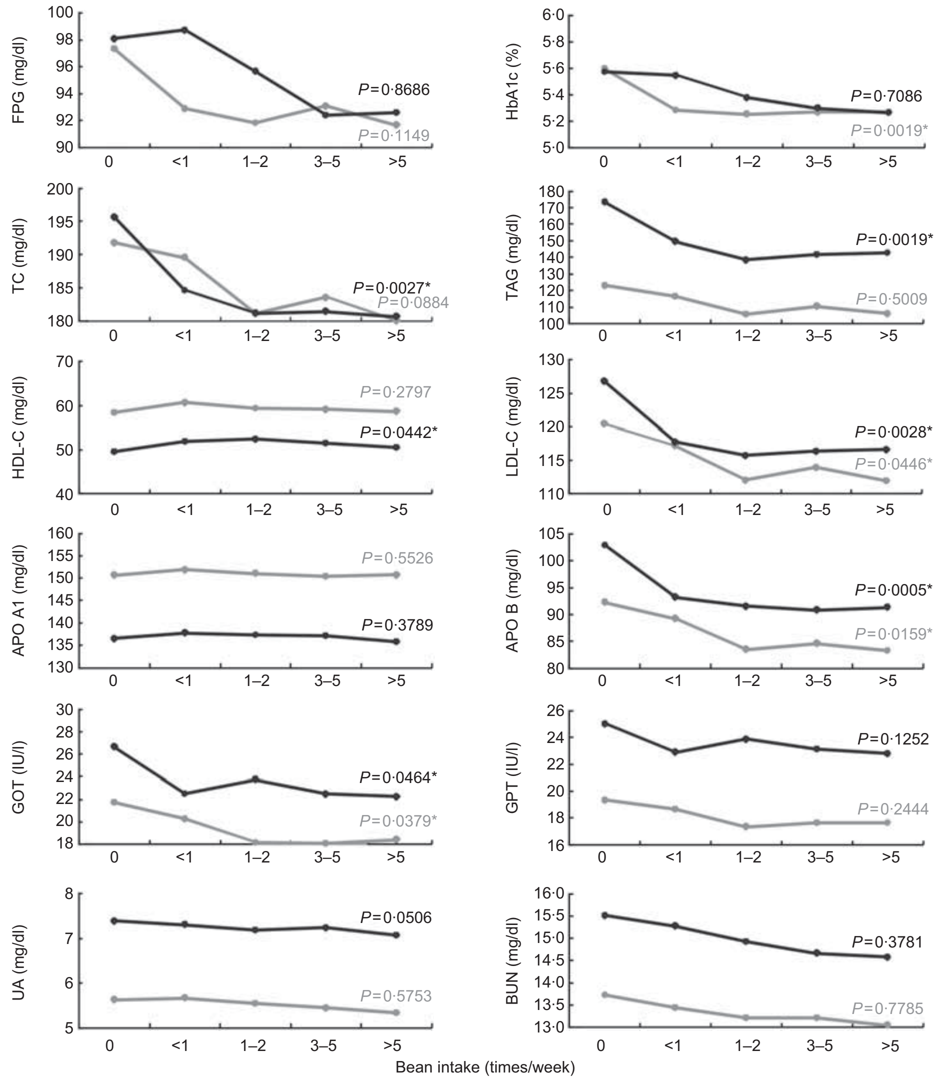

Fig. 3 Patterns of blood analytes (FPG, fasting plasma glucose; HbA1c, glycated Hb; TC, total cholesterol; HDL-C, HDL cholesterol; LDL-C, LDL cholesterol; GOT, glutamic oxaloacetic transaminase; GPT, glutamic pyruvic transaminase; UA, uric acid; BUN, blood urea nitrogen) across bean intake frequencies by gender (—, men; —, women) in Taiwanese adults. $*P < 0{\cdot}05$; generalized linear models adjusting for age were used to test least-square means between participants with a bean-free diet (0 times/week) and those with a bean diet (<1, 1–2, 3–5, >5 times/week) through the coefficient set of linear combinations as (−1, 0·25, 0·25, 0·25, 0·25)

resistant starch; essential fatty acids; a high arginine (nitrous oxide precursor) content of protein; bioactive peptides such as lunasin, phytosterols and phyo-oestrogenic isoflavones; and other compounds. These components have unique physico-chemical properties as well, which are conducive to slower and lower glycaemic responses to diet[23]. Collectively, these properties can ameliorate the risk of CVD and diabetes as posed by body compositional, blood pressure and metabolic pathways[24]. This, in turn, can translate into reduced female mortality, as shown by the present and other studies[8–11].

Metabolic syndrome and bean intake

There is gender consistency in the risk of a low intake or bean-free diet for the NCEP-tw MetS and with different numbers of components from 0 to 5. However, the dose–response pattern of increasing bean intake frequency differs by gender. This may represent different MetS susceptibilities in men and women, with concomitant differences in the impact of protectants like beans. We have previously reported that hypertension and hypertriacylglycerolaemia are more prevalent in Taiwanese men than women[16], and therefore it seems that more effect of antihypertensive or antihypertriacylglycerolaemic properties of beans might be observed in men. Likewise, the effects of phyto-oestrogen-rich beans on hormone-sensitive body fat distribution (WC and WHR) might be similarly evident, although from gender-different anatomical reference points. It is interesting why there should be lower HbA1c with greater bean intake frequency in

Table 3 Associations between a bean-free diet, MetS and total deaths as OR for NCEP-tw MetS scores, or HR and PAR of all-cause mortality, based on data from NHIS 2001 and TwSHHH 2002†, and the link to Death Records 2002–2008

	Cross-sectional analysis NHIS 2001 and TwSHHH 2002*				Longitudinal analysis Baselines linked to death records 2002–2008					
	NCEP-tw MetS scores†‡				All-cause mortality‡§				Mortality PAR	
	Males		Females		Males		Females			
Baseline variables	OR	95 % CI	OR	95 % CI	HR	95 % CI	HR	95 % CI	Males %	Females %
Model 1										
Bean-free diet	↑ 1·83	1·34, 2·49	↑ 1·45	1·05, 2·01	1·28	0·76, 2·16	↑ 1·98	1·03, 3·81	2·73	7·33
NCEP-tw MetS (yes *v.* no)	—		—		1·19	0·83, 1·72	↑ 1·75	1·07, 2·84	4·96	18·99
Model 2 (stratified by BMI groups)										
Bean-free diet					1·34	0·79, 2·27	↑ 2·13	1·10, 4·13	3·17	7·85
NCEP-tw MetS (yes *v.* no)					↑ 1·59	1·05, 2·38	↑ 1·97	1·18, 3·30	11·28	21·87
TC<200 mg/dl (yes *v.* no)					↑ 1·65	1·11, 2·46	1·16	0·73, 1·83	30·45	7·33

MetS, metabolic syndrome; NCEP-tw, Taiwanese-modified National Cholesterol Education Program–Adult Treatment Panel III; HR, hazard ratio; PAR, population-attributable risk; NHIS, National Health Interview Survey; TwSHHH, Taiwanese Survey of Hyperglycaemia, Hyperlipidaemia and Hypertension; MET metabolic equivalent task; HRT, hormone replacement therapy.

†The cumulative logistical models were applied to explore cross-sectional association between NCEP-tw MetS scores and the bean-free diet based on data from NHIS 2001 (demography, diet history, and health behaviours interview) and TwSHHH 2002 (medical history, physical examinations and blood analytes).

‡Adjusted for baseline variables, including age (in 10-year increments), socio-economic status (low, middle, high), meat intake, fish/seafood intake, dairy products intake, grain intake ≥3 bowls/d, dark-green vegetables intake, fruit intake >5 times/week, baked products/sweets/chocolate, iced food/sweetened soft drink/cola, high fat intake, coffee or tea intake, current alcohol drinker, current smoker ≥100 lifetime cigarettes, current betel-nut chewer, physical activity (per 10 MET-h/week) and HRT.

§All-cause mortality: Cox proportional hazard model was applied to calculate the HR and 95 % CI through the baseline data set (NHIS 2001 and TwSHHH 2002) linked to the eventual death records from 2002 to 2008. Stratified BMI groups (<18·5, 18·5–22·9, 23·0–24·9, 25·0–29·9, ≥30 kg/m^2) were used in model 2.

women, but not in men; neither gender displayed a relationship with FPG. The difference between the FPG and HbA1c findings suggests a greater effect of bean intake on postprandial glycaemia than on hepatic nocturnal gluconeogenesis. It is noteworthy that in both genders bean intake is protectant against liver dysfunction mainly in GOT rather than in GPT, which could be relevant to the reduction of fatty liver disease. These differences in the relationships between bean intake and MetS components, even though a bean-free diet is adverse for the NCEP-tw MetS scores in both genders, are consistent with an adverse impact greater in men than in women.

All-cause mortality and bean intake

Our study suggests that bean intake is a better protectant against mortality in women than men. The reverse is apparently the case for gender and MetS, although OR are significant for both genders. Neither the bean-free diet nor NCEP-tw MetS itself predicts all-cause mortality as well in men as in women. Thus, there would appear to be different contributors by gender to MetS and differences as to how MetS contributes to potential morbidity (such as body compositional disorders, hypertension, CVD and diabetes) and all-cause mortality. For morbidity, as judged by the MetS, bean intake appears to be relevant in both genders; but, for mortality, it has a greater impact on risk in women. One reason may be that MetS is a better predictor of all-cause mortality in women than men[25]. Another consideration is that malignant neoplasms were the leading cause and contributed to 37 % of female deaths among which breast cancers took the major toll. However, the low case rates do not allow us to consider disease-specific mortalities in this cohort. Nevertheless, MetS appears to be a risk for cancer[26].

Population-attributable risk for mortality

For Taiwanese women, the HR shows that a bean-free diet is a significant risk factor for all-cause mortality; but the PAR reflects that it is relatively uncommon. In women, a bean-free diet has about one-third of all-cause mortality PAR compared with that of the NCEP-tw MetS regardless of BMI stratification or TC adjustment (Table 3). However, through BMI stratifications and TC adjustment in men, the PAR of NCEP-tw MetS changes sharply beyond that of a bean-free diet. The hazard functions for the five BMI classifications differ only insofar as they have different baseline hazard functions. Nevertheless, this is the consequence of stratification of the BMI variable, and it is not possible to obtain an HR value or mortality PAR for the effect of BMI with adjustment for other variables.

Limitations

One limitation of the present study is that there was a refusal rate (of about 10 %) in the TwSHHH 2002 among those individuals who accepted the household interview but refused to provide blood samples. A TwSHHH 2002 report has indicated that the gender ratio distributions were not significantly different nor were the ages different between the target study population (*n* 10 292) and the total eligible participants (*n* 7578) who responded to the TwSHHH questionnaire administered in various areas[27,28]. It is, therefore, unlikely that this refusal rate would have created any meaningful demographic difference between the target study population (*n* 10 292) and the actual study participants (*n* 6600). Nevertheless, the reduced participation rate may have created a non-response bias towards exclusion of either participants with the poorest health outcomes or of participants with other concerns (such as additional medical involvement, time-consuming examinations, a painful venepuncture or uncertain consequences). Second, the NHIS 2001 study objective was not only about nutrition and therefore used a truncated FFQ. However, major food categories in the twenty-item questionnaire are similar to those in a sixty-four-item and a thirty-seven-item Chinese FFQ used and validated in Taiwan[29,30]. Food culture is extremely well developed in Taiwan in families, communities, events, schools, workplaces, the media, among celebrities and in commerce; its pursuance and its nuances are likely to have a role in health that the present study has not penetrated. Third, recent evidence has cast doubt on the nature of fat intake as a risk factor for CVD[31]. Fat intake may be protective against the NCEP-tw MetS and this might be explained by its effect in lowering the glycaemic response through slower gastric emptying or with various degrees of the consumption of plant (soya) and different fatty acid patterns from vegetable cooking oil, fish, pork (dependent on the feed type) and chicken. We had no opportunity to examine these possibilities. Finally, we have adjusted for HRT use yet Chinese women have not used HRT to the same extent as European women, perhaps because of concerns about adverse effects of HRT such as stroke, venous thromboembolism and certain cancers (breast/uterus). We were unable to disaggregate the types of oestrogen replacement therapy with or without progestin replacement therapy. It would be interesting to know if there were any synergies between the effects of beans and HRT on all-cause mortality.

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