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Original article

Association of dietary patterns with serum high-sensitivity C-reactive protein level in community-dwelling older adults

Ruth Chan [a,*], Blanche Yu [a,b], Jason Leung [b], Jenny Shun-Wah Lee [a], Jean Woo [a,c]

[a] Department of Medicine and Therapeutics, The Chinese University of Hong Kong, Shatin, Hong Kong
[b] Jockey Club Centre for Osteoporosis Care and Control, The Chinese University of Hong Kong, Shatin, Hong Kong
[c] Jockey Club Institute of Ageing, The Chinese University of Hong Kong, Shatin, Hong Kong

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S U M M A R Y

Introduction: Studies examining the association between dietary patterns and inflammatory markers are limited, in particular among Chinese older adults.
Objective: We examined the association of various dietary patterns with serum high-sensitivity C-reactive protein (hsCRP) level in community-dwelling Chinese older adults, taking into account demographics and other lifestyle factors.
Methods: We conducted ordinal regression analyses using baseline data based on 1332 older men and 1314 older women of Chinese origin from a cohort study of bone health in Hong Kong. Baseline interviewer administered questionnaires included dietary intake estimation and dietary pattern generation from the food frequency questionnaire, as well as demographic and lifestyle factors. Serum hsCRP was measured using a commercially available enzyme-linked immunosorbent assay.
Results: In men, higher serum hsCRP level was associated with lower Diet Quality Index-International (DQI-I) score, the Mediterranean-DASH Intervention for Neurodegenerative Delay diet (MIND) score, Okinawan diet score, "vegetables-fruits" pattern score, and lower adherence to the Mediterranean diet. In women, serum hsCRP level was not associated with any dietary patterns.
Conclusion: Our cross-sectional analyses suggest that various dietary patterns were associated with a lower serum hsCRP level in community-dwelling Chinese older adults, and these associations were only observed in older men.

1. Introduction

A state of low-grade inflammation has been linked with obesity and a wide range of non-communicable conditions, such as metabolic syndrome, diabetes, non-alcoholic fatty liver disease, and cardiovascular disease (CVD) [1–3]. High-sensitivity C-reactive protein (hsCRP), which is synthesized mainly in the liver in response to interleukin-6, is one of the well-recognized markers for "inflammageing" [4] and has been associated with many age-related chronic diseases [4–6].

Several risk factors including body mass index, smoking and physical inactivity have been reported to be associated with hsCRP [7,8]. The influence of diet on hsCRP has been documented mainly among adolescents and adults [9–11]. The findings generally suggested that a diet of increased consumption of vegetables and fruits, whole grain cereals, nuts and healthy oils, as well as low intake of meat, sugary drinks, processed foods and unhealthy oils was associated with lower hsCRP level [9]. However, limited studies have been conducted among older adults, in particular among Chinese [12,13]. Moreover, most studies have examined the association of diet with hsCRP using individual food group or single nutrient approach, rather than dietary pattern approach [2,9]. Since diet is a combination of long-term, multiple exposures of food and nutrients, the dietary pattern approach based on existing patterns and/or that generated from a local population using principal component analysis [14–16] is preferred over the single nutrient/food group approach to examine the role of diet on chronic diseases and mortality.

* Corresponding author. Department of Medicine and Therapeutics, Prince of Wales Hospital, Shatin, N.T., Hong Kong. Fax: +852 2637 9215.
E-mail address: ruthchansm@cuhk.edu.hk (R. Chan).

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Based on available data from the Mr and Ms Os study cohorts consisting of 4000 Chinese people aged 65 years and over in Hong Kong, we examined the influence of various dietary patterns on hsCRP, taking into account age, gender, and other lifestyle risk factors.

2. Subjects and methods

Subjects were participants of a prospective cohort study examining the risk factors for osteoporosis in Hong Kong [17]. 2000 men and 2000 women aged 65 years and over living in the community were recruited between 2001 and 2003 by placing recruitment notices in community centers for the older people and housing estates, using a stratified sample so that approximately 33% would be in each of these age groups: 65–69, 70–74, and 75+. Participants were volunteers and were able to walk or take public transport to the study site. Compared with the general population in this age group, participants had higher educational level (12–18% vs. 3–9% with tertiary education in the age groups 80+, 75–79,70–74, and 65–69 years [18]. This study followed the guidelines laid down in the Declaration of Helsinki, and was approved by the Clinical Research Ethics Committee of the Chinese University of Hong Kong. Written informed consent was obtained from all subjects. Among 4000 subjects, six subjects were excluded due to extremely high (5000 kcal/day), low (500 kcal/day) energy intake or incomplete dietary data. Moreover, those with missing serum data due to limited funding resource (n = 1182), extreme hsCRP level (>10 mg/L) (n = 165) and missing data on alcohol use (n = 1) were excluded. The final sample included in the analysis was 1332 men and 1314 women (Fig. 1).

A standardized, structured interview was performed to collect information on age, gender, smoking habit, alcohol use and self-reported medical history. Self-reported medical history was obtained based on participants' report of their physician's diagnoses of a list of common medical conditions, such as diabetes, hypertension, cardiovascular diseases, osteoporosis, and Parkinson's disease, supplemented by the identification of all medications brought to the interviewers.

Physical activity was assessed by the Physical Activity Scale for the Elderly (PASE) [19]. This is a 12-item scale measuring the average number of hours per day spent in leisure, household, and occupational physical activities over the previous 7-day period. Activity weights for each item were determined based on the amount of energy spent, and each item score was calculated by multiplying the activity weight with daily activity frequency. A composite PASE score of all the items was calculated, a higher score reflecting higher physical activity level.

Dietary intake was assessed at baseline using a validated food frequency questionnaire (FFQ) developed in a population survey with participants aged between 25 and 74 years, the validity of which has been described elsewhere [20]. Mean nutrient quantitation per day was calculated using food composition tables derived from McCance and Widdowson [21] and the Chinese Medical Sciences Institute [22]. The FFQ consisted of 280 food items. Each participant was asked to complete the questionnaire – the food item, the size of each portion, the number of times of consumption each day and each week, using the past 12 months prior to the interview as a reference period. Portion size was explained to participants using a catalogue of pictures of individual food portions.

2.1. Dietary patterns derived by factor analysis

Individual food items from the FFQ were aggregated into 32 food groups based on similarity of type of food and nutrient composition. The food groups were energy adjusted by dividing the energy intake from each food group by total energy intake and multiplying by 100, and were expressed as percentage contribution to total energy. The factor scores for each pattern were calculated for each subject by summing intakes of food items weighted by their factor loadings. A higher score indicated greater conformity with the pattern being calculated. Factor analysis identified three dietary patterns in men and women: vegetables-fruits pattern, snacks-drinks-milk products pattern, and meat-fish pattern [14].

2.2. Diet Quality Index-International (DQI-I)

The Diet Quality Index-International (DQI-I) was used to assess the quality of diet [23], since it is an indicator of dietary patterns in relation to health. The DQI-I has also been used to evaluate the quality of diet in a Chinese population [24]. Four major aspects of the diet are assessed: variety, adequacy, moderation and overall balance, each with subcomponents. The range is 0–100, with high score indicating high quality. In this study, we did not have sufficient information to calculate the category of empty-calorie foods under the aspect 'moderation'. Therefore, the range of score for moderation was 0–24 instead of 0–30, and the DQI-I total score was 0–94 instead of 0–100.

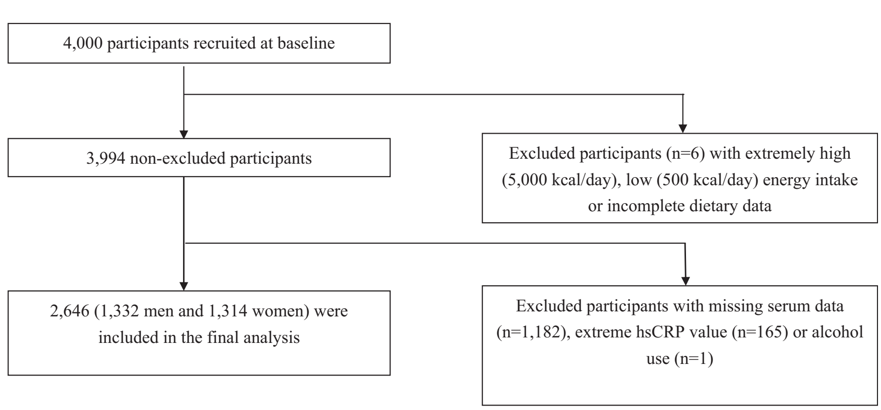

Fig. 1. Participant flow chart.

2.3. The Mediterranean Diet Score (MDS)

Adherence to the Mediterranean diet was calculated using the revised method described by Trichopoulou et al. (2003) [25]. Essentially, adherence is represented by a scale where a value of 1 was assigned to consumption of food groups considered beneficial to health at or above the sex-specific median (vegetables, legumes, fruits and nuts, cereal, fish and monosaturated to saturated lipids ratio) and below the median for food groups presumed to be detrimental to health (meat, poultry and dairy products). The component of ethanol consumption was scored 1 if daily consumption was between 10 and 50 g for men or 5 and 25 g for women. Therefore, the total MDS ranged from 0 (minimal adherence to the traditional Mediterranean diet) to 9 (maximal adherence).

2.4. The Dietary Approaches to Stop Hypertension (DASH) score

The DASH diet emphasizes foods rich in protein, fiber, potassium, magnesium, and calcium, such as fruits and vegetables, beans, nuts, whole grains and low-fat dairy, limiting foods high in saturated fat and sugar [26]. A DASH score based on the score developed by Mellen et al. [27] was used to assess accordance with the DASH dietary pattern. The score is based on DASH target intakes for nine nutrients including total fat, saturated fat, protein, fiber, cholesterol, calcium, magnesium, potassium and sodium. Achieving each nutrient target was given a score of 1, and meeting a nutrient target which was intermediate between the DASH target and the nutrient content of the diet of the control group in the DASH trial was given a score of 0.5. The total DASH score was generated by summing the score for each nutrient target with a range from 0 to 9. Higher total DASH score indicates better DASH accordance.

2.5. The Mediterranean-DASH Intervention for Neurodegenerative Delay diet (MIND) score

This diet is based on the Mediterranean and DASH diets, with the additional emphasis on ten food groups that is related to slower decline in cognitive abilities: green leafy vegetables, other vegetables, nuts, berries, beans, whole grains, seafood, poultry, olive oil and wine and five unhealthy food groups (red meats, butter and stick margarine, cheese, pastries and sweets, and fried/fast food) [28]. A score of 0, 0.5 or 1 was assigned to each food group according to the frequency and portion consumed except for olive oil [28]. For olive oil, score of 1 was given if it was used as usual primary oil at home to give a total score of 15 [28]. In this study, we did not have enough information to identify use of olive oil as primary oil and the consumption frequency of fish (not fried), beans, poultry, red meat and products, and fast fried foods. Therefore the maximum score of MIND in this study was 9 instead of 15. Higher total MIND score indicates better MIND accordance.

2.6. The Okinawan diet score

The traditional Okinawan diet is anchored by root vegetables, with relatively low calorie intake and shares many features with the Mediterranean and DASH diets [29]. According to Willcox et al. (2007) [29], the consumed food groups and the concordance energy intake of the traditional Okinawan diet were as below: rice (12% of total calories), wheat, barley and other grains (7% of total calories), nuts and seeds (<1% of total calories), sugars (<1% of total calories), oils (2% of total calories), legumes (6% of total calories), fish (1% of total calories), meat (including poultry) (<1% of total calories), eggs (<1% of total calories), dairy (<1% of total calories), sweet potatoes (69% of total calories), other potatoes (<1% of total calories), other vegetables (3% of total calories), fruit (<1% of total calories), seaweed (<1% of total calories), pickled vegetables (0% of total calories), flavors & alcohol (<1% of total calories). Each food group mentioned above was scored 1 if the ratio of energy intake achieved the concordance % of total calories. As we did not have the information of seaweed intake, in calculation of the Okinawan diet score, seaweed intake was not included, therefore the maximum Okinawan diet score was 16.

2.7. Anthropometric measurements

Body weight was measured to the nearest 0.1 kg with participants wearing a light gown, using the Physician Balance Beam Scale (Healthometer, Illinois, USA). Height was measured to the nearest 0.1 cm using the Holtain Harpenden stadiometer (Holtain Ltd, Crosswell, UK). Body mass index (BMI) was calculated as body weight in kg/(height in m)^2.

2.8. Laboratory measurements

Fasting serum samples were collected at baseline and stored at −80 °C. hsCRP level was measured in duplicates using a commercially available enzyme-linked immunosorbent assay (Vitros Fusion 5,1, Vitros Chemistry Products, USA) and was performed by PathLab Co. Ltd. The intra-assay and inter-assay coefficient of variations (CVs) were 1.1–1.4% and 3.7–6.2% respectively.

2.9. Statistical analysis

Statistical analyses were performed separately for men and women using the statistical package SPSS version 24 (IBM SPSS Statistics for Windows, Version 24.0. Armonk, NY: IBM Corp.). The three dietary pattern scores derived by the factor analysis, the DQI-I total score, the MIND score, the Okinawan diet score were stratified into tertiles based on the distribution of each sex. The MDS was divided into three levels of adherence, namely low (0–3), medium [4,5] and high (≥6) [25,30]. The DASH score was divided into two levels of accordance, using a total DASH score of at least 4.5 as a cutoff value [27]. Serum hsCRP level was stratified into three categories, namely low (<1 mg/L), average (1–3 mg/L) and high (3.1–10 mg/L) [31]. The differences in baseline characteristics and hsCRP level across tertiles or categories of each dietary pattern score in men and women were examined using chi square test for categorical variables and by one way ANOVA test or independent t-test for continuous variables, or corresponding non-parametric tests where appropriate. Since the majority of missing data was due to the unavailability of serum hsCRP data in this study (Fig. 1), the differences in baseline characteristics between those included in the final analysis and those without serum hsCRP data were also examined using chi square test for categorical variables and by independent t-test for continuous variables.

Ordinal logistic regression analysis was used to examine odds ratios (ORs) and 95% confidence intervals (CIs) for risk of average or high level of hsCRP according to tertiles of each dietary pattern score or three levels of MDS or the DASH accordance. Model 1 was unadjusted model. Model 2 was adjusted for baseline age (years) and BMI (kg/m^2). Model 3 was further adjusted for daily energy intake (kcal), current smoker, current alcohol use, PASE and number of diseases. Test for trend was examined by entering tertiles of each dietary pattern score or three levels of MDS as a continuous variable in all models whereas p value between two levels of DASH accordance was examined by entering two levels of DASH accordance as a continuous variable in all models. Analysis of covariance (ANCOVA) was also used to examine the association of mean serum hsCRP level across categories of each dietary pattern in both

Table 1
Baseline characteristics by dietary pattern scores in men (n = 1332).

Parameters	DQI					DASH					MIND					MDS				
	T1 (n=416)		T3 (n=488)			Low (n=938)		High (n=394)			T1 (n=536)		T3 (n=313)			T1 (n=441)		T3 (n=245)		
	mean / n	SD / %	mean / n	SD / %	p-trend[a]	mean / n	SD / %	mean / n	SD / %	p-value[b]	mean / n	SD / %	mean / n	SD / %	p-trend[a]	mean / n	SD / %	mean / n	SD / %	p-trend[a]
Age (year)	72.6	5.1	72.6	5.2	0.853	72.6	5.2	72.5	5.1	0.826	73.1	5.3	72.0	4.9	**0.003**	72.5	5.3	72.2	5.0	0.548
BMI (kg/m^2)	23.7	3.4	23.5	2.8	0.307	23.6	3.2	23.5	3.0	0.611	23.3	3.3	23.8	2.9	**0.012**	23.4	3.2	24.1	3.1	**0.005**
Current Smoker	72	17.3%	39	8.0%	**<0.001**	117	12.5%	31	7.9%	**0.015**	70	13.1%	28	8.9%	0.055	60	13.6%	20	8.2%	**0.024**
Current Drinker	103	24.8%	97	19.9%	0.074	233	24.8%	74	18.8%	**0.017**	68	12.7%	112	35.8%	**<0.001**	92	20.9%	63	25.7%	0.134
No. of diseases					0.882					0.118					0.098					0.278
0-1 disease	181	43.5%	215	44.1%		427	45.5%	161	40.9%		468	87.3%	259	82.7%		378	85.7%	218	89.0%	
≥2 diseases	235	56.5%	273	55.9%		511	54.5%	233	59.1%		68	12.7%	54	17.3%		63	14.3%	27	11.0%	
PASE total score	87.6	47.6	100.5	48.2	**<0.001**	95.8	49.4	95.5	47.9	0.918	89.6	47.7	99.6	44.8	**0.004**	91.5	50.1	101.7	48.5	**0.009**
Daily energy intake (kcal/day)	2020.2	673.3	2195.3	551.4	**<0.001**	2126.5	616.3	2039.5	541.5	**0.010**	1983.1	557.3	2254.9	607	**<0.001**	1894.8	538.2	2316.0	581.8	**<0.001**
hsCRP (mg/L)[c]	1.7	0.8-3.1	1.3	0.7-2.5	**<0.001**	1.5	0.8-2.8	1.4	0.7-2.7	0.336	1.5	0.8-3.1	1.4	0.7-2.6	**0.035**	1.7	0.8-3.5	1.4	0.7-3.0	0.246

Parameters	Okinawan					Factor 1: Vegetables-fruits					Factor 2: Snacks-drinks-milk products					Factor 3: Meat-fish				
	T1 (n=428)		T3 (n=559)			T1 (n=443)		T3 (n=444)			T1 (n=444)		T3 (n=445)			T1 (n=444)		T3 (n=444)		
	mean / n	SD / %	mean / n	SD / %	p-trend[a]	mean / n	SD / %	mean / n	SD / %	p-trend[a]	mean / n	SD / %	mean / n	SD / %	p-trend[a]	mean / n	SD / %	mean / n	SD / %	p-trend[a]
Age (year)	72.9	5.1	72.3	5.2	**0.050**	72.2	4.9	72.7	5.2	0.185	72.9	4.9	72.1	5.3	**0.014**	72.3	5.0	72.7	5.3	0.195
BMI (kg/m^2)	23.6	3.4	23.5	2.9	0.780	23.3	3.3	23.8	3.0	**0.039**	23.7	3.2	23.5	3.1	0.404	23.4	3.0	23.8	3.2	0.134
Current Smoker	52	12.2%	57	10.2%	0.330	75	16.9%	27	6.1%	**<0.001**	49	11.0%	53	11.9%	0.678	41	9.2%	54	12.2%	0.165
Current Drinker	64	15.0%	160	28.6%	**<0.001**	107	24.2%	82	18.5%	**0.044**	78	17.6%	126	28.3%	**<0.001**	75	16.9%	133	30.0%	**<0.001**
No. of diseases					**0.029**					0.333					0.370					**0.011**
0-1 disease	385	90.0%	475	85.0%		388	87.6%	379	85.4%		381	85.8%	391	87.9%		398	89.6%	372	83.8%	
≥2 diseases	43	10.0%	84	15.0%		55	12.4%	65	14.6%		63	14.2%	54	12.1%		46	10.4%	72	16.2%	
PASE total score	91.7	46.6	99.2	49.9	**0.017**	91.6	48.2	98.8	52.5	**0.028**	95.8	48.8	98.5	50.7	0.422	95.8	47.7	96.4	51.1	0.860
Daily energy intake (kcal/day)	2021.3	569.7	2139.5	596.5	**0.002**	2043.5	568.8	2138.9	641.3	**0.017**	1962.7	544.3	2251.3	614.6	**<0.001**	1994.4	549.2	2209.8	648.3	**<0.001**
hsCRP (mg/L)[c]	1.7	0.9-3.3	1.4	0.7-2.8	**0.005**	1.8	0.9-3.7	1.5	0.7-2.9	**0.002**	1.5	0.8-3.0	1.4	0.7-2.6	0.054	1.4	0.7-2.8	1.5	0.8-2.9	0.101

Bold figures indicate p value <0.05.

[a] Linear trend test by Chi-square test (categorical variables) or one way ANOVA test or non-parametric Krusall-Wallis test (continuous variables) where appropriate.

[b] p value by Chi-square test (categorical variables) or independent t test or non-parametric Mann-Whitney U test (continuous variables) where appropriate.

[c] Median (interquarter range).

Table 2
Baseline characteristics by dietary pattern scores in women (n = 1314).

Parameters	DQI					DASH					MIND					MDS				
	T1 (n = 434)		T3 (n = 442)			Low (n = 652)		High (n = 662)			T1 (n = 432)		T3 (n = 349)			T1 (n = 489)		T3 (n = 236)		
	mean/n	SD/%	mean/n	SD/%	p-trend[a]	mean/n	SD/%	mean/n	SD/%	p-value[b]	mean/n	SD/%	mean/n	SD/%	p-trend[a]	mean/n	SD/%	mean/n	SD/%	p-trend[a]
Age (year)	72.8	5.6	72.2	5.1	0.121	72.9	5.5	72.4	5.3	0.121	73.2	5.8	71.8	5.1	**<0.001**	72.7	5.6	72.4	5.1	0.431
BMI (kg/m^2)	23.7	3.5	23.7	3.1	0.865	23.9	3.5	23.8	3.3	0.497	24	3.4	23.6	3.4	0.158	23.8	3.3	23.9	3.2	0.935
Current Smoker	14	3.2%	1	0.2%	**0.001**	14	2.1%	8	1.2%	0.185	12	2.8%	2	0.6%	**0.016**	12	2.5%	0	0.0%	**0.020**
Current Drinker	14	3.2%	14	3.2%	0.964	19	2.9%	17	2.5%	0.701	7	1.6%	13	3.7%	0.069	12	2.5%	8	3.4%	0.490
No. of diseases					0.265					0.304					0.422					0.660
0-1 disease	183	42.2%	203	45.9%		283	43.4%	306	46.2%		371	85.9%	292	83.7%		423	86.5%	210	89.0%	
≥2 diseases	251	57.8%	239	54.1%		369	56.6%	356	53.8%		61	14.1%	57	16.3%		66	13.5%	26	11.0%	
PASE total score	81.7	31.3	89.4	33.7	**0.001**	84.2	33.4	86.8	33.3	0.170	81.2	31.4	89.4	34.6	**0.001**	84.5	37.2	89.2	32	0.074
Daily energy intake (kcal/day)	1422.0	495.6	1759.3	414.3	**<0.001**	1611.1	483.9	1551.3	440.1	**0.019**	1457.8	451.8	1728.1	462.8	**<0.001**	1428.9	402.8	1799.8	452.4	**<0.001**
hsCRP (mg/L)[c]	1.7	0.8–3.5	1.6	0.8–3.1	0.524	1.7	0.8–3.5	1.6	0.9–3.1	0.652	1.8	0.8–3.5	1.7	0.8–3.4	0.752	1.8	0.9–3.4	1.7	0.8–3.4	0.589
Parameters	**Okinawan Score**					**Factor 1: Vegetables-fruits**					**Factor 2: Snacks-drinks-milk products**					**Factor 3: Meat-fish**				
	T1 (n = 427)		T3 (n = 486)			T1 (n = 439)		T3 (n = 439)			T1 (n = 438)		T3 (n = 439)			T1 (n = 438)		T3 (n = 439)		
	mean/n	SD/%	mean/n	SD/%	p-trend[a]	mean/n	SD/%	mean/n	SD/%	p-trend[a]	mean/n	SD/%	mean/n	SD/%	p-trend[a]	mean/n	SD/%	mean/n	SD/%	p-trend[a]
Age (year)	72.6	5.3	72.4	5.5	0.490	73.2	5.5	72.1	5.3	**0.003**	72.8	5.1	72.2	5.7	0.110	72.7	5.6	72.7	5.5	0.962
BMI (kg/m^2)	24	3.2	23.8	3.5	0.320	23.8	3.4	23.9	3.4	0.520	24.2	3.5	23.7	3.4	**0.032**	23.4	3.3	24.1	3.4	**0.001**
Current Smoker	9	2.1%	7	1.4%	0.440	15	3.4%	4	0.9%	**0.004**	8	1.8%	11	2.5%	0.433	9	2.1%	9	2.1%	0.996
Current Drinker	8	1.9%	14	2.9%	0.374	10	2.3%	15	3.4%	0.299	4	0.9%	14	3.2%	**0.039**	10	2.3%	18	4.1%	0.099
No. of diseases					**0.016**					0.912					**0.001**					0.181
0-1 disease	360	84.3%	436	89.7%		376	85.6%	374	85.4%		364	83.1%	399	90.9%		384	87.7%	371	84.5%	
≥2 diseases	67	15.7%	50	10.3%		63	14.4%	64	14.6%		74	16.9%	40	9.1%		54	12.3%	68	15.5%	
PASE total score	85.3	32.4	87.6	35.6	0.283	83.2	32.6	87.6	34.3	0.051	85.8	31.4	86.5	36.6	0.735	87.6	33	82.7	32.2	**0.029**
Daily energy intake (kcal/day)	1511.4	463.7	1638.3	474.7	**<0.001**	1507.5	425.0	1661.0	524.2	**<0.001**	1439.0	396.3	1740.4	513.1	**<0.001**	1477.7	398.1	1685.8	523.9	**<0.001**
hsCRP (mg/L)[c]	1.8	0.9–3.3	1.6	0.8–3.4	0.830	1.6	0.8–3.4	1.7	0.9–3.2	0.539	1.8	0.8–3.4	1.6	0.8–3.2	0.754	1.6	0.8–3.3	1.8	0.9–3.3	0.183

Bold figures indicate p value <0.05.
[a] Linear trend test by Chi-square test (categorical variables) or one way ANOVA test or non-parametric Krusall-Wallis test (continuous variables) where appropriate.
[b] p value by Chi-square test (categorical variables) or independent t test or non-parametric Mann-Whitney U test (continuous variables) where appropriate.
[c] Median (interquarter range).

Table 3
Ordinal logistic regression linking serum hsCRP categories and different diet pattern groups in men (n = 1332).

Diet pattern	hsCRP level						OR (95% CI)		
	Low <1.0 mg/L		Average 1.0–3.0 mg/L		High 3.1–10 mg/L		Model 1 - unadjusted	Model 2[a]	Model 3[b]
DQI									
T1 (0–59)	(n = 120)	28.8%	(n = 189)	45.4%	(n = 107)	25.7%	reference	reference	reference
T2 (60–68)	(n = 135)	31.5%	(n = 192)	44.9%	(n = 101)	23.6%	0.88 (0.69,1.14)	0.90 (0.70,1.16)	0.93 (0.72,1.20)
T3 (69–87)	(n = 182)	37.3%	(n = 220)	45.1%	(n = 86)	17.6%	**0.66 (0.51,0.84)**	**0.67 (0.52,0.85)**	**0.68 (0.53,0.88)**
						p-trend	**0.001**	**0.001**	**0.003**
DASH									
Low (≤4)	(n = 303)	32.3%	(n = 425)	45.3%	(n = 210)	22.4%	reference	reference	reference
High (≥4.5)	(n = 134)	34.0%	(n = 176)	44.7%	(n = 84)	21.3%	0.93 (0.75,1.16)	0.94 (0.76,1.18)	0.95 (0.76,1.19)
						p-value	0.524	0.609	0.641
MIND									
T1 (2–4)	(n = 153)	28.5%	(n = 248)	46.3%	(n = 135)	25.2%	reference	reference	reference
T2 (4.5–5)	(n = 172)	35.6%	(n = 211)	43.7%	(n = 100)	20.7%	**0.74 (0.59,0.93)**	**0.72 (0.57,0.91)**	**0.73 (0.57,0.92)**
T3 (5.5–7.5)	(n = 112)	35.8%	(n = 142)	45.4%	(n = 59)	18.8%	**0.71 (0.55,0.92)**	**0.67 (0.52,0.88)**	**0.68 (0.52,0.90)**
						p-trend	**0.005**	**0.002**	**0.003**
MDS									
T1 (0–3)	(n = 133)	30.2%	(n = 199)	45.1%	(n = 109)	24.7%	reference	reference	reference
T2 (4–5)	(n = 218)	33.7%	(n = 291)	45.0%	(n = 137)	21.2%	0.84 (0.67,1.05)	0.81 (0.65,1.02)	0.81 (0.64,1.02)
T3 (6–9)	(n = 86)	35.1%	(n = 111)	45.3%	(n = 48)	19.6%	0.78 (0.58,1.04)	**0.70 (0.52,0.95)**	**0.71 (0.52,0.96)**
						p-trend	0.065	**0.015**	**0.020**
Okinawan									
T1 (3–6)	(n = 120)	28.0%	(n = 206)	48.1%	(n = 102)	23.8%	reference	reference	reference
T2 (7)	(n = 108)	31.3%	(n = 157)	45.5%	(n = 80)	23.2%	0.90 (0.69,1.18)	0.89 (0.69,1.17)	0.89 (0.68,1.17)
T3 (8–12)	(n = 209)	37.4%	(n = 238)	42.6%	(n = 112)	20.0%	**0.71 (0.56,0.9)**	**0.73 (0.57,0.93)**	**0.74 (0.58,0.94)**
						p-trend	**0.004**	**0.009**	**0.014**
HK diet pattern									
Factor 1: vegetables–fruits									
T1	(n = 125)	28.2%	(n = 205)	46.3%	(n = 113)	25.5%	reference	reference	reference
T2	(n = 148)	33.3%	(n = 206)	46.3%	(n = 91)	20.4%	**0.78 (0.61,0.99)**	**0.72 (0.56,0.93)**	**0.73 (0.57,0.93)**
T3	(n = 164)	36.9%	(n = 190)	42.8%	(n = 90)	20.3%	**0.70 (0.54,0.89)**	**0.62 (0.48,0.80)**	**0.63 (0.49,0.81)**
						p-trend	**0.004**	**<0.001**	**<0.001**
Factor 2: snacks–drinks–milk products									
T1	(n = 134)	30.2%	(n = 204)	45.9%	(n = 106)	23.9%	reference	reference	reference
T2	(n = 144)	32.5%	(n = 198)	44.7%	(n = 101)	22.8%	0.92 (0.72,1.17)	0.95 (0.74,1.22)	0.94 (0.73,1.21)
T3	(n = 159)	35.7%	(n = 199)	44.7%	(n = 87)	19.6%	**0.78 (0.61,0.99)**	0.82 (0.64,1.05)	0.82 (0.64,1.06)
						p-trend	**0.045**	0.116	0.134
Factor 3: meat-fish									
T1	(n = 159)	35.8%	(n = 187)	42.1%	(n = 98)	22.1%	reference	reference	reference
T2	(n = 137)	30.9%	(n = 215)	48.4%	(n = 92)	20.7%	1.11 (0.87,1.42)	1.08 (0.85,1.39)	1.07 (0.83,1.37)
T3	(n = 141)	31.8%	(n = 199)	44.8%	(n = 104)	23.4%	1.15 (0.90,1.48)	1.06 (0.83,1.36)	1.07 (0.83,1.38)
						p-trend	0.253	0.629	0.598

Bold figures indicate p value <0.05.
[a] Model 2 - adjusted for age and BMI.
[b] Model 3 - further adjusted for daily energy intake, current smoking status, current drinker status, PASE score and number of diseases.

unadjusted and adjusted models. Test for trend was examined by entering categories of dietary pattern as a fixed factor and testing the contrast by polynomial option in all models.

Since chronic diseases might lead the participants to change their diet and affect inflammatory status, all analyses were repeated by excluding participants with chronic diseases to examine whether the associations between dietary patterns and serum hsCRP level were attenuated by the presence of chronic diseases. A p value <0.05, 2 sided was considered as statistically significant.

3. Results

3.1. Participants' characteristics between those included in the final analysis and those without serum hsCRP data

For both men and women, significant differences were only noted for few baseline characteristics between those who were included in the final analysis and those did not have serum hsCRP data. Men who did not have serum hsCRP data were older and less physically active. They also showed higher BMI and lower “meat-fish” dietary pattern score. For women, those who did not have serum hsCRP showed lower DQI-I score (details not shown).

3.2. Participants' characteristics across tertiles or categories of each dietary pattern score

Baseline characteristics of men and women according to each dietary pattern score are shown in Tables 1 and 2 respectively. In men, lifestyle profiles and demographic characteristics differed significantly across tertiles or categories of the dietary pattern scores. Higher tertile of DQI-I score, MIND score, Okinawan diet score and “vegetables-fruits” dietary pattern score as well as higher adherence to the Mediterranean diet were associated with higher PASE score. All dietary pattern scores except DASH score were positively associated with daily energy intake. Higher tertile of DQI-I score and “vegetables-fruits” dietary pattern score, as well as higher adherence to the DASH diet and the Mediterranean diet were associated with lower proportion of current smoker. While higher tertile of “vegetables-fruits” dietary pattern score and higher adherence to DASH diet were associated with lower proportion of current drinker, higher adherence to other dietary patterns including MIND diet, Okinawan diet, “snacks-drinks-milk” dietary pattern, and "meat-fish" dietary pattern were associated with higher proportion of current drinker. hsCRP level was inversely associated with DQI-I score, MIND score, Okinawan diet score and "vegetables-fruits" dietary pattern score (Table 1).

In women, higher tertile of DQI-I score and MIND score were associated with higher PASE score, whereas higher tertile of "meat-fish" dietary pattern score was associated with lower PASE score. All dietary pattern scores except DASH diet score were associated with higher daily energy intake. Higher tertile of the DQI-I score, MIND score, and "vegetables-fruits" dietary pattern as well as higher adherence to the Mediterranean diet were associated with lower proportion of current smoker. Higher tertile of "snacks-drinks-milk" dietary pattern was associated with higher proportion of current alcohol use. hsCRP level was not associated with any dietary patterns in women (Table 2).

3.3. Dietary patterns and serum level of hsCRP

In men, higher DQI-I score, MIND score, Okinawan score, "vegetable-fruits" dietary pattern score, as well as "snacks-drinks-milk products" dietary pattern score were significantly associated with lower hsCRP level in the unadjusted model (p-trend all <0.05). The significant associations were observed for DQI-I score, MIND score, MDS, Okinawan diet score, and "vegetable-fruits" dietary pattern score after adjustment for the demographic variables and lifestyle risk factors (Table 3). In women, none of the dietary pattern scores were associated with hsCRP level in both unadjusted and adjusted models (Table 4). Results from ANCOVA analyses showed similar results (Tables 5 and 6).

Further analyses by excluding participants with chronic diseases showed that the significant inverse associations of serum hsCRP level with dietary pattern scores only remained for MIND score and "vegetable-fruits" dietary pattern score in men after adjustment for the demographic variables and lifestyle risk factors. In addition, a significant positive association between serum hsCRP level and "meat-fish" dietary pattern score was noted in men in the adjusted models (Supplementary Tables 1 and 3). In women, the results were similar to those including participants with chronic diseases (Supplementary Tables 2 and 4).

4. Discussion

Our study show that dietary patterns examined in the study are associated with serum level of hsCRP, independent of personal demographic and lifestyle factors in community-dwelling older Chinese adults in Hong Kong. However, such associations were only

Table 4
Ordinal logistic regression linking serum hsCRP categories and different diet pattern groups in women (n = 1314).

Diet pattern	hsCRP level						OR (95% CI)		
	Low <1.0 mg/L		Average 1.0–3.0 mg/L		High 3.1–10 mg/L		Model 1 - unadjusted	Model 2[a]	Model 3[b]
DQI									
T1 (0–61)	(n = 130)	30.0%	(n = 168)	38.7%	(n = 136)	31.3%	reference	reference	reference
T2 (62–69)	(n = 127)	29.0%	(n = 189)	43.2%	(n = 122)	27.9%	0.94 (0.73,1.20)	0.87 (0.68,1.12)	0.90 (0.70,1.16)
T3 (70–90)	(n = 127)	28.7%	(n = 204)	46.2%	(n = 111)	25.1%	0.89 (0.69,1.13)	0.88 (0.68,1.12)	0.93 (0.72,1.21)
						p-trend	0.333	0.307	0.598
DASH									
Low (≤4)	(n = 199)	30.5%	(n = 257)	39.4%	(n = 196)	30.1%	reference	reference	reference
High (≥4.5)	(n = 185)	27.9%	(n = 304)	45.9%	(n = 173)	26.1%	0.97 (0.79,1.18)	0.99 (0.81,1.21)	0.995 (0.81,1.22)
						p-value	0.755	0.926	0.962
MIND									
T1 (2–4)	(n = 125)	28.9%	(n = 172)	39.8%	(n = 135)	31.3%	reference	reference	reference
T2 (4.5–5)	(n = 156)	29.3%	(n = 244)	45.8%	(n = 133)	25.0%	0.85 (0.67,1.08)	0.86 (0.68,1.09)	0.89 (0.70,1.13)
T3 (5.5–7.5)	(n = 103)	29.5%	(n = 145)	41.5%	(n = 101)	28.9%	0.93 (0.72,1.21)	1.00 (0.77,1.31)	1.05 (0.80,1.38)
						p-trend	0.536	0.925	0.802
MDS									
T1 (0–3)	(n = 133)	27.2%	(n = 212)	43.4%	(n = 144)	29.4%	reference	reference	reference
T2 (4–5)	(n = 186)	31.6%	(n = 241)	40.9%	(n = 162)	27.5%	0.86 (0.69,1.07)	0.86 (0.69,1.08)	0.88 (0.70,1.11)
T3 (6–9)	(n = 65)	27.5%	(n = 108)	45.8%	(n = 63)	26.7%	0.93 (0.70,1.24)	0.92 (0.69,1.23)	0.98 (0.72,1.32)
						p-trend	0.426	0.415	0.684
Okinawan									
T1 (3–6)	(n = 118)	27.6%	(n = 182)	42.6%	(n = 127)	29.7%	reference	reference	reference
T2 (7)	(n = 119)	29.7%	(n = 178)	44.4%	(n = 104)	25.9%	0.87 (0.67,1.12)	0.89 (0.69,1.15)	0.90 (0.69,1.16)
T3 (8–12)	(n = 147)	30.2%	(n = 201)	41.4%	(n = 138)	28.4%	0.91 (0.71,1.15)	0.95 (0.75,1.22)	0.98 (0.77,1.26)
						p-trend	0.445	0.716	0.911
HK diet pattern									
Factor 1: vegetables–fruits									
T1	(n = 128)	29.2%	(n = 179)	40.8%	(n = 132)	30.1%	reference	reference	reference
T2	(n = 137)	31.4%	(n = 179)	41.1%	(n = 120)	27.5%	0.89 (0.69,1.13)	0.88 (0.69,1.13)	0.89 (0.70,1.15)
T3	(n = 119)	27.1%	(n = 203)	46.2%	(n = 117)	26.7%	0.97 (0.76,1.24)	0.95 (0.74,1.21)	0.98 (0.76,1.26)
						p-trend	0.797	0.680	0.885
Factor 2: snacks–drinks–milk products									
T1	(n = 125)	28.5%	(n = 184)	42.0%	(n = 129)	29.5%	reference	reference	reference
T2	(n = 129)	29.5%	(n = 184)	42.1%	(n = 124)	28.4%	0.95 (0.74,1.22)	1.04 (0.81,1.34)	1.08 (0.84,1.39)
T3	(n = 130)	29.6%	(n = 193)	44.0%	(n = 116)	26.4%	0.91 (0.71,1.16)	1.00 (0.78,1.28)	1.05 (0.81,1.36)
						p-trend	0.425	0.974	0.724
Factor 3: meat-fish									
T1	(n = 136)	31.1%	(n = 181)	41.3%	(n = 121)	27.6%	reference	reference	reference
T2	(n = 129)	29.5%	(n = 188)	43.0%	(n = 120)	27.5%	1.03 (0.81,1.32)	0.94 (0.73,1.21)	0.97 (0.75,1.24)
T3	(n = 119)	27.1%	(n = 192)	43.7%	(n = 128)	29.2%	1.14 (0.90,1.46)	1.01 (0.79,1.29)	1.04 (0.81,1.34)
						p-trend	0.282	0.949	0.764

[a] Model 2 - adjusted for age and BMI.
[b] Model 3 - further adjusted for daily energy intake, current smoking status, current drinker status, PASE score and number of diseases.

Table 5
Mean (standard error) of serum hsCRP level across categories of dietary pattern in men (n = 1332).

Diet pattern		Mean (SE) hsCRP level (mg/L)		
		Model 1 - unadjusted	Model 2[a]	Model 3[b]
DQI				
T1 (0–59)	(n = 416)	1.557 (1.049)	1.541 (1.048)	1.627 (1.057)
T2 (60–68)	(n = 428)	1.364 (1.049)	1.371 (1.047)	1.488 (1.061)
T3 (69–87)	(n = 488)	1.212 (1.046)	1.217 (1.044)	1.322 (1.060)
	p-trend	**<0.001**	**<0.001**	**0.001**
DASH				
Low (≤4)	(n = 938)	1.384 (1.033)	1.381 (1.032)	1.506 (1.047)
High (≥4.5)	(n = 394)	1.308 (1.051)	1.316 (1.049)	1.437 (1.064)
	p-value	0.336	0.403	0.421
MIND				
T1 (2.0–4.0)	(n = 536)	1.469 (1.044)	1.483 (1.042)	1.608 (1.057)
T2 (4.5–5.0)	(n = 483)	1.309 (1.046)	1.302 (1.044)	1.433 (1.057)
T3 (5.5–7.5)	(n = 313)	1.268 (1.057)	1.259 (1.055)	1.396 (1.067)
	p-trend	**0.035**	**0.017**	**0.044**
MDS				
T1 (0–3)	(n = 441)	1.426 (1.048)	1.448 (1.046)	1.559 (1.059)
T2 (4–5)	(n = 646)	1.354 (1.040)	1.357 (1.038)	1.483 (1.053)
T3 (6–9)	(n = 245)	1.269 (1.065)	1.229 (1.063)	1.360 (1.075)
	p-trend	0.139	**0.031**	0.082
Okinawan				
T1 (3–6)	(n = 428)	1.454 (1.049)	1.439 (1.047)	1.563 (1.061)
T2 (7)	(n = 345)	1.459 (1.054)	1.453 (1.053)	1.587 (1.064)
T3 (8–12)	(n = 559)	1.240 (1.043)	1.253 (1.041)	1.382 (1.055)
	p-trend	**0.012**	**0.024**	**0.046**
HK diet pattern				
Factor 1: vegetables–fruits				
T1	(n = 443)	1.524 (1.048)	1.565 (1.046)	1.665 (1.057)
T2	(n = 445)	1.306 (1.048)	1.298 (1.046)	1.401 (1.059)
T3	(n = 444)	1.267 (1.048)	1.242 (1.046)	1.348 (1.062)
	p-trend	**0.005**	**<0.001**	**0.001**
Factor 2: snacks–drinks–milk products				
T1	(n = 444)	1.457 (1.048)	1.431 (1.046)	1.561 (1.060)
T2	(n = 443)	1.356 (1.048)	1.357 (1.046)	1.481 (1.059)
T3	(n = 445)	1.276 (1.048)	1.298 (1.046)	1.432 (1.059)
	p-trend	**0.045**	0.130	0.189
Factor 3: meat-fish				
T1	(n = 444)	1.294 (1.048)	1.314 (1.046)	1.429 (1.061)
2	(n = 444)	1.351 (1.048)	1.357 (1.046)	1.469 (1.059)
T3	(n = 444)	1.442 (1.048)	1.414 (1.046)	1.554 (1.058)
	p-trend	0.101	0.256	0.196

Bold figures indicate p value <0.05.
[a] Model 2 - adjusted for age and BMI.
[b] Model 3 - further adjusted for daily energy intake, current smoking status, current drinker status, PASE score and number of chronic diseases.

Table 6
Mean (standard error) of serum hsCRP level across categories of dietary pattern in women (n = 1314).

Diet pattern		Mean (SE) hsCRP level (mg/L)		
		Model 1 - unadjusted	Model 2[a]	Model 3[b]
DQI				
T1 (0–61)	(n = 434)	1.534 (1.051)	1.550 (1.048)	1.614 (1.146)
T2 (62–69)	(n = 438)	1.567 (1.051)	1.520 (1.048)	1.608 (1.150)
T3 (70–90)	(n = 442)	1.467 (1.050)	1.497 (1.048)	1.608 (1.151)
	p-trend	0.524	0.599	0.961
DASH				
Low (≤4)	(n = 652)	1.542 (1.041)	1.528 (1.039)	1.614 (1.144)
High (≥4.5)	(n = 662)	1.503 (1.041)	1.516 (1.039)	1.606 (1.146)
	p-value	0.652	0.879	0.922
MIND				
T1 (2.0–4.0)	(n = 432)	1.582 (1.051)	1.549 (1.048)	1.622 (1.148)
T2 (4.5–5.0)	(n = 533)	1.461 (1.046)	1.459 (1.043)	1.550 (1.146)
T3 (5.5–7.5)	(n = 349)	1.545 (1.057)	1.590 (1.054)	1.703 (1.151)
	p-trend	0.752	0.715	0.500
MDS				
T1 (0–3)	(n = 489)	1.607 (1.048)	1.605 (1.045)	1.684 (1.147)
T2 (4–5)	(n = 589)	1.449 (1.043)	1.451 (1.041)	1.535 (1.146)
T3 (6–9)	(n = 236)	1.538 (1.070)	1.537 (1.066)	1.649 (1.158)
	p-trend	0.589	0.579	0.794
Okinawan				
T1 (3–6)	(n = 427)	1.543 (1.051)	1.516 (1.048)	1.592 (1.149)
T2 (7)	(n = 401)	1.503 (1.053)	1.517 (1.050)	1.602 (1.148)
T3 (8–12)	(n = 486)	1.520 (1.048)	1.532 (1.045)	1.636 (1.148)
	p-trend	0.830	0.874	0.672
HK diet pattern				
Factor 1: vegetables –fruits				
T1	(n = 439)	1.520 (1.051)	1.518 (1.048)	1.590 (1.146)
T2	(n = 436)	1.461 (1.051)	1.470 (1.048)	1.556 (1.151)
T3	(n = 439)	1.587 (1.051)	1.580 (1.048)	1.684 (1.149)
	p-trend	0.539	0.542	0.387
Factor 2: snacks–drinks–milk products				
T1	(n = 438)	1.542 (1.051)	1.490 (1.048)	1.544 (1.151)
T2	(n = 437)	1.517 (1.051)	1.536 (1.048)	1.624 (1.149)
T3	(n = 439)	1.508 (1.051)	1.541 (1.048)	1.637 (1.146)
	p-trend	0.754	0.613	0.392
Factor 3: meat-fish				
T1	(n = 438)	1.462 (1.051)	1.529 (1.048)	1.592 (1.149)
T2	(n = 437)	1.503 (1.051)	1.481 (1.048)	1.562 (1.151)
T3	(n = 439)	1.604 (1.051)	1.557 (1.048)	1.645 (1.146)
	p-trend	0.183	0.778	0.625

[a] Model 2 - adjusted for age and BMI.
[b] Model 3 - further adjusted for daily energy intake, current smoking status, current drinker status, PASE score and number of chronic diseases.

observed in men, in that lower serum hsCRP level was associated with higher tertile of DQI-I score, MIND score, Okinawan diet score, “vegetable-fruits” dietary pattern score, as well as greater adherence to the Mediterranean diet. Analyses by excluding participants with chronic diseases further confirmed the association of serum hsCRP level with selected dietary patterns including MIND, “vegetable-fruits” dietary pattern and “meat-fish” dietary pattern in men but not in women. The gender difference in the results of dietary patterns and hsCRP may be explained by the observations that men in general showed less healthy dietary patterns and lifestyles than women. Therefore data from men maybe more heterogeneous compared with women, in which benefit of selected dietary patterns was more easily to be detected in this study.

Our findings were in general in line with the observations from the literature. Several studies have been conducted to examine the association of dietary patterns with CRP level. A higher diet quality defined using the a priori approach, such as alternate Mediterranean Diet Index [32] or Mediterranean dietary pattern [33], and alternative Healthy Eating Index (HEI) [34], was associated with a lower level of CRP. Studies using the a posteriori approach to generate dietary patterns mostly suggested that a Western dietary pattern and a dietary pattern characterized with a high meat, instant food, fat and sugar intake were related to an increased serum level of hsCRP [10,13,35], whereas an inverse association of a healthy dietary pattern score or a vegetable and fruit rich dietary pattern score with hsCRP level was reported in other studies [36,37].

Among all the dietary pattern scores, i.e. the DQI-I score, the MIND score, the Okinawan diet score, the “vegetable-fruits” dietary pattern score and the adherence to the Mediterranean diet, that showed an inverse association with serum level of hsCRP in our study, there are common features to all these scores, for example in emphasizing fruit and vegetable intakes. The DQI-I score also constitutes a comprehensive diet quality score covering different aspects of diet, including variety, adequacy, moderation and overall balance, and represents a balanced diet with diverse and adequate nutrient intakes and food group consumption, in particular the consumption of vegetables and fruits. Our findings further support previous observations that a normocaloric diet with moderate intake of carbohydrate and protein, high intake of healthy fats and low glycemic index foods, and limited intake of saturated fat could help prevent and improve low-grade inflammation [9].

There are several limitations in this study. The study is cross sectional in design and can only address associations and not causation because the risk factor and the outcome are obtained at the same time in cross sectional study. For causation analysis, the risk factor should be assessed before outcome. In addition, our sample was of a higher educational standard compared with the general Hong Kong population and the results may not be extrapolated to the general population. Moreover, there were differences in a few baseline characteristics between those who did not have serum hsCRP data and those who were included for the final analysis, and such differences may attenuate the association between dietary patterns and serum hsCRP level. Besides, only single assessment of serum hsCRP level was available in this study. Some investigations suggested that serum hsCRP levels might be variable within an individual and multiple assessments are therefore more valid to assess the inflammatory status of participants [38].

In conclusion, various dietary patterns were associated with a lower serum hsCRP level in community-dwelling Chinese older adults, and such associations were only observed in older men. The study findings highlight the importance of diet influence in inflammageing.

Author contributions

RC contributed to the conception and design of the study, the interpretation of data, and drafting of the manuscript. BY, JL and JSWL contributed to the acquisition of data, as well as the analysis and interpretation of data. JW contributed to the conception and design of the study and critical revision of the manuscript for important intellectual input. All authors approved the manuscript before submission.

Conflict of interest

The authors declare no conflict of interest associated with this manuscript.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.clnesp.2019.03.004.

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