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ORIGINAL CONTRIBUTION

Habitual consumption of coffee and green tea in relation to serum adipokines: a cross-sectional study

Ngoc Minh Pham · Akiko Nanri · Kazuki Yasuda · Kayo Kurotani · Keisuke Kuwahara · Shamima Akter · Masao Sato · Hitomi Hayabuchi · Tetsuya Mizoue

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Abstract
Purpose Coffee and green tea consumption may be associated with circulating adipokines, but data are inconsistent, scarce or lacking. We examined the association of coffee and green tea consumption with serum adiponectin, leptin, visfatin, resistin and plasminogen activator inhibitor-1 (PAI-1) among a Japanese working population.
Methods The authors analyzed data ($n = 509$) from a cross-sectional survey among Japanese workers aged 20–68 years. Serum adipokines were measured using a Luminex suspension bead-based multiplexed array. Coffee and green tea consumption was assessed using a validated diet history questionnaire, and caffeine consumption from these beverages was estimated. Multiple regression analysis was performed with adjustment for potential confounding variables.
Results Coffee consumption was significantly, inversely associated with leptin and PAI-1 (P for trend = 0.007 and 0.02, respectively); compared with subjects consuming <1 cup per day, those consuming ≥4 cups per day had 13 and 10 % lower means of leptin and PAI-1, respectively. Similar associations were observed for caffeine consumption (P for trend = 0.02 for both leptin and PAI-1). Additionally, we noted a significant positive association between coffee consumption and adiponectin in men (P for trend = 0.046), but not in women (P for trend = 0.43, P for interaction = 0.11). Moreover, there was a positive association between coffee consumption and resistin in current male smokers (P for trend = 0.01), but not in male non-smokers (P for trend = 0.35, P for interaction = 0.11). Green tea consumption was not associated with any adipokine.
Conclusions Higher consumption of coffee and caffeine but not green tea was associated with lower serum levels of leptin and PAI-1 in Japanese adults.

Keywords Coffee · Green tea · Adipokines · Japanese

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N. M. Pham (✉) · A. Nanri · K. Kurotani · K. Kuwahara · S. Akter · T. Mizoue
Department of Epidemiology and Prevention, Center for Clinical Sciences, National Center for Global Health and Medicine, Toyama 1-21-1, Shinjuku-ku, Tokyo 162-8655, Japan
e-mail: minh.pn@tnu.edu.vn

K. Yasuda
Department of Metabolic Disorder, Diabetes Research Center, National Center for Global Health and Medicine, Tokyo, Japan

M. Sato
Department of Applied Biological Chemistry, Graduate School of Bioresource and Bioenvironmental Sciences, Kyushu University, Fukuoka, Japan

H. Hayabuchi
Graduate School of Nutrition and Health Science, Fukuoka Women's University, Fukuoka, Japan

Introduction

Coffee and tea are the two most popular beverages worldwide, and their health effects have attracted increasing attention [1, 2]. Accumulating evidence suggests that coffee consumption affords protection against type 2 diabetes (T2D) [3] and cancer [4]. Likewise, habitual green tea consumption, a widely consumed tea among Asians, is reportedly associated with lower risk of some types of cancer, such as colorectal cancer [5]. Attempts have been

made to decipher pathways underlying potentially beneficial roles of these two beverages against risks of T2D [6, 7] and cancer [8, 9]. Studies have linked circulating adipokines, which are hormones and cytokines produced by adipose tissues, to metabolic diseases [10]. Among the adipokines, adiponectin and leptin are major hormones secreted exclusively by the adipocytes and of considerable interest. It has been shown that adiponectin was inversely, whereas leptin was positively, associated with T2D [11, 12] and cancer risk [13]. Other adipokines, namely resistin, visfatin and plasminogen activator inhibitor-1 (PAI-1) have also been shown to be unfavorably associated with cancer risk [14–16]. It remains unclear whether a beneficial effect of coffee and green tea consumption against T2D and cancer is operated through improved adipokine profile.

Evidence for the association between coffee and green tea consumption and adipokines is inconsistent, scarce or lacking. Several studies showed a higher level of circulating adiponectin with increasing coffee consumption [17–23], while others did not [24, 25]. Few studies have examined the association between coffee consumption and circulating leptin, showing an inverse association [22, 26] or no change in serum leptin at higher levels of coffee consumption [18]. As for other adipocytokines including resistin, visfatin and PAI-1, we are aware of only one clinical study reporting an increase in plasma PAI-1 in heavy coffee drinkers than in light coffee drinkers [27]. Concerning green tea, no association with adiponectin [19, 25] and no effect on leptin [28] were reported. Coffee and green tea are a major source of caffeine, and studies of caffeine consumption and adipokines are limited, with one showing a positive association with adiponectin in US diabetic, but not non-diabetic women [17] and another one reporting an inverse association between caffeine consumption and plasma leptin [29].

Moreover, there is a sex difference in distribution of two major adipokines, leptin and adiponectin [30], which may lead to differential associations between them and consumption of coffee and green tea. However, this issue has received less attention. We thus conducted the present study to examine cross-sectionally the association of consumption of coffee, green tea and caffeine with serum adipokine among a Japanese working population. We hypothesized that higher consumption of these beverages is associated with higher adiponectin concentrations, but is associated with lower concentrations of leptin, resistin, visfatin and PAI-1.

Subjects and methods

Study procedure and subjects

The present study was based on surveys among municipal employees of two municipal offices in northeastern Kyushu, Japan (conducted in July 2009 in one office and November 2009 in another). Details of the survey have been described elsewhere [31]. Briefly, of all workers in these municipal offices ($n = 605$, mainly administrators, nurses and school lunch preparers) who were invited to the survey, 567 (325 men and 242 women aged 20–68 years) agreed to take part in this study (response rate 94 %). Participants were invited to fill in a survey questionnaire before the health checkup. The survey questionnaire was checked by research staff for completeness, and where necessary, clarifications were made with the subjects on the day of health examination. We also obtained data that were routinely collected in the health examination, including anthropometric measurements, biochemical data and information about medical history, smoking and alcohol drinking. We excluded participants who reported having a history of diabetes ($n = 8$), cancer ($n = 13$), cardiovascular disease ($n = 11$), nephritis ($n = 1$) and those receiving medical care for chronic hepatitis ($n = 3$). Additionally, we excluded pregnant participants ($n = 8$). Those who had missing data on serum adipokines ($n = 17$) were further excluded. Some of the excluded subjects had two or more conditions for exclusion, leaving a total of 509 subjects (296 men and 213 women). Of these, we retained 506 subjects for the analysis of visfatin after excluding those with visfatin levels below ($n = 2$) or above ($n = 1$) the detection limits. Data for the analysis of leptin included subjects under fasting condition ($n = 486$). The study protocol was reviewed and approved by the Ethics Committee of the National Center for Global Health and Medicine, Japan. Written informed consent was obtained from all subjects prior to the survey.

Laboratory procedures

Blood samples were obtained on the day of the health checkup. Venous blood (7 mL) was drawn into vacuum tubes and transported in a cooler box to the laboratory. Serum samples for measurement of adipokines were stored at −80 °C until biochemical assay. To quantify serum concentrations of adiponectin, leptin, resistin, visfatin and PAI-1, a Luminex suspension bead-based multiplexed array was performed using Bio-Plex 3D suspension array system and Bio-Plex Pro human diabetes assay panel (Bio-Rad Laboratories, Hercules, CA); the intra-assay coefficients of variation were 12 % for adiponectin, 11 % for leptin, 8 % for resistin, 19 % for visfatin and 21 % for PAI-1. Luminex technology, which enables simultaneous assessment of multiple biomarkers, has been widely used. The system requires only a small amount of clinical samples, and good correlation with ELISA and the usefulness for epidemiological studies have been well demonstrated [32].

Dietary assessment

Information about dietary intake during the preceding month was obtained using a validated brief self-administered diet history questionnaire (BDHQ) [33], which ascertained frequency of 46 food and non-alcoholic beverage items, including coffee and green tea. The response options for coffee or green tea consumption were never, <1 cup/week, 1 cup/week, 2–3 cups/week, 4–6 cups/week, 1 cup/day, 2–3 cups/day and ≥4 cups/day. Dietary energy and intakes of selected nutrients were estimated using an ad hoc computer algorithm with reference to the Standard Tables of Food Composition in Japan [34]. Correlations between consumptions of coffee and green tea according to the above-mentioned BDHQ and those from 16-day dietary records were high (Spearman's $r = 0.83$ and 0.77 for coffee in men and women, respectively; Spearman's $r = 0.68$ and 0.64 for green tea in men and women, respectively) [33]. To estimate caffeine consumption from coffee and green tea consumption, a value (cups/week) was, respectively, assigned to the above-mentioned consumption frequency of these beverages, namely 0, 0.5, 1, 2.5, 5, 7, 17.5 and 28. A cup size of green tea or coffee was specified as 173 ml for men and 150 ml for women [33]. According to the Food Composition Table in Japan [34], 100 ml of coffee and green tea contains approximately 60 and 20 mg of caffeine, respectively.

Other variables

Marital status, job position, alcohol and tobacco use, occupational and types of occupation were elicited in the questionnaire. Occupational physical activity was classified as sedentary work and active work. Questions on non-occupational physical activity ascertained daily minutes spent for walking or cycling for commuting to or from work, and five recreational activities (walking, low-, moderate-, and high-intensity activities and gardening). Non-occupational physical activity was estimated in metabolic equivalent value [35] and expressed as sum of MET multiplied by the time (in hours) spent performing each activity. Body height was measured to the nearest 0.1 cm with subjects standing without shoes. Body weight in light clothes was measured to the nearest 0.1 kg. Body mass index (BMI) was calculated by dividing weight by squared height (kg/m^2).

Statistical analysis

The descriptive data were presented as the mean (standard deviation), median (interquartile range) or percentages. Coffee drinkers were divided into four groups: consuming <1, 1, 2–3 or ≥4 cups/day; green tea drinkers were categorized into three groups: consuming ≤1, 2–3 or ≥4 cups/day. Caffeine consumption was classified into quartiles (≤100, 101–159, 160–291 or ≥292 mg/day). Characteristics according to categories of coffee and green tea consumption were evaluated using ANOVA and Kruskal–Wallis tests for normal and non-normal continuous variables, respectively, and χ^2 test for trend for categorical variables. Analysis of covariance was performed to estimate geometric means and 95 % confidence intervals of adipokine concentrations after log transformation. Multiple linear regression was used to test the trend of association between coffee, green tea and caffeine consumption and serum adipokines by assigning ordinal numbers to the consumption categories of coffee, green tea and caffeine. We first adjusted for age (continuous), sex and workplace (site A or B) (model 1). Second, we adjusted for job position (low or middle and high), occupational physical activity (active or sedentary), non-occupational physical activity (<5 or ≥5 MET-hr/week), smoking status (never smokers, ex-smokers, current smokers consuming 1–19 cigarettes/day or current smokers consuming ≥20 cigarettes/day), alcohol drinking (non-drinker and current drinker consuming alcohol <1 day/week or current drinker consuming alcohol ≥1 days/week), total energy intake (log-transformed, continuous), mutual adjustment for green tea consumption (≤1, 2–3 or ≥4 cups/day) and coffee consumption (<1, 1 or ≥2 cups/day), hypertension (yes or no) defined as systolic blood pressure of ≥140 mmHg or diastolic blood pressure of ≥90 mmHg or current use of antihypertensive drugs, hyperlipidemia (yes or no) defined as serum low-density lipoprotein cholesterol ≥160 mg/dl [36] or current use of antihyperlipidemic drugs, BMI (continuous) and use of non-steroid anti-inflammatory drugs (yes or no) (model 2). In addition, we performed stratified analyses of coffee consumption and serum adipokines according to sex, BMI (<23 or ≥23 kg/m^2) and smoking status (in male only: non-smoker or current smoker). Statistical test for interaction was conducted by likelihood ratio test, comparing multiple linear models with and without an interaction term with full adjustment for covariates. The interaction term was generated by multiplying each dichotomized variable mentioned above by categories of coffee, green tea or caffeine consumption, with beverage consumption categories being treated as continuous variables. Two-sided *P* values of less than 0.05 were considered statistically significant. All analyses were performed using Stata version 12.1 (StataCorp, College Station, TX, USA).

Results

Subject characteristics according to coffee and green tea consumption are summarized in Table 1. Individuals with a higher consumption of coffee were older, less likely to be engaged in sedentary work and more likely to be current smokers. Those with a higher consumption of green tea

Table 1 Characteristics of the study subjects according to coffee and green tea consumption

Characteristics	Coffee consumption (cup/day)					Green tea consumption (cup/day)			
	<1	1	2–3	≥4	*P* value[a]	≤1	2–3	≥4	*P* value[a]
No. of subjects[b]	196	111	155	47		258	162	89	
Age (y), mean (SD)	41.4 (11.6)	43.4 (11.0)	45.9 (10.2)	44.0 (8.7)	**0.002**	42.7 (10.8)	44.4 (10.8)	43.9 (11.5)	0.28
Women, %	38.3	41.4	47.1	40.4	0.42	28.3	51.2	64.0	**<0.001**
BMI (kg/m^2), mean (SD)	22.2 (3.3)	22.2 (3.4)	22.5 (3.3)	22.7 (3.0)	0.73	22.6 (3.1)	22.2 (3.3)	21.7 (3.7)	0.09
Workplace (site A)[c] (%)	31.1	31.5	27.7	23.4	0.67	30.2	30.3	25.8	0.71
Sedentary work (%)	88.8	79.3	75.5	72.3	**0.004**	83.0	78.4	80.9	0.51
Job position (low) (%)	60.7	61.3	54.8	51.1	0.45	59.7	53.1	62.9	0.25
Non-occupational physical activity (≥5 MET-hr/week) (%)	34.5	37.8	33.6	42.6	0.66	38.0	32.1	36.0	0.47
Use of anti-inflammatory drugs (%)	10.2	4.5	6.5	14.9	0.09	8.1	4.9	14.6	**0.03**
Current smoking (%)	19.4	25.2	29.0	36.2	0.052	31.8	21.6	12.4	**0.001**
Current drinking (%)	61.7	57.7	64.5	57.5	0.66	69.8	54.3	49.4	**<0.001**
Total energy intake (kcal/day), median (IQR)	1,762 (1,404–2,114)	1,731 (1,318–2,104)	1,773 (1,459–2,030)	1,667 (1,464–2,066)	0.94	1,736 (1,417–2,090)	1,769 (1,430–1,993)	1,759 (1,434–2,155)	0.54
Coffee consumption (≥1 cup/day) (%)	–	–	–	–		64.7	60.5	53.9	0.19
Green tea consumption (≥1 cup/day) (%)	67.9	73.0	67.7	53.2	0.12	–	–	–	
Caffeine consumption (mg/d), median (IQR)	85 (43–124)	137 (120–188)	291 (261–342)	435 (412–444)	**0.0001**	127 (71–269)	165 (122–300)	210 (144–345)	**0.0001**
Hypertension (%)	14.8	10.8	14.2	6.4	0.38	12.8	11.7	15.7	0.66
Hyperlipidemia[d] (%)	13.3	14.4	20.7	21.3	0.21	15.5	20.4	12.4	0.22

Bold values indicate statistical significance

BMI body mass index, *IQR* interquartile range, *MET-hr* metabolic equivalent hours, *SD* standard deviation

[a] Based on ANOVA and Kruskal–Wallis tests for normal and non-normal continuous variables and χ^2 test for categorical variables

[b] Data for adiponectin, resistin and plasminogen activator inhibitor-1. Numbers of subjects for visfatin and leptin were different because those who had outlier values (visfatin) and were not fasting (leptin) were excluded. Numbers for visfatin were 195, 109, 155 and 47, and 257, 160 and 89 across increasing levels of coffee and green tea consumption, respectively; the corresponding figures for leptin were 184, 107, 149 and 46 for coffee, and 244, 158 and 84 for green tea

[c] Survey conducted in July 2009

[d] Serum low-density lipoprotein cholesterol ≥160 mg/dl or current use of antihyperlipidemic medication

Table 2 Geometric means (95 % CI) of serum concentrations of adipokines according to coffee and green tea consumption

Serum adipokines	Coffee consumption (cup/day)					Green tea consumption (cup/day)			
	<1	1	2–3	≥4	P^{a}_{trend}	≤1	2–3	≥4	P^{a}_{trend}
No. of subjects[b]	196	111	155	47		258	162	89	
Adiponectin (μg/ml)									
Model 1[c]	4.64 (4.23–5.08)	4.92 (4.37–5.55)	4.96 (4.48–5.50)	4.98 (4.15–5.99)	0.61	4.69 (4.33–5.09)	4.85 (4.39–5.36)	5.19 (4.53–5.95)	0.23
Model 2[d]	4.68 (4.27–5.13)	4.86 (4.32–5.48)	4.85 (4.38–5.37)	5.32 (4.42–6.41)	0.30	4.68 (4.32–5.08)	4.87 (4.41–5.38)	5.19 (4.52–5.95)	0.22
Leptin (ng/ml)									
Model 1[c]	1.88 (1.66–2.13)	1.83 (1.56–2.15)	1.52 (1.33–1.75)	1.68 (1.31–2.14)	0.055	1.72 (1.54–1.92)	1.78 (1.56–2.03)	1.70 (1.41–2.04)	0.98
Model 2[d]	1.91 (1.73–2.11)	1.84 (1.62–2.09)	1.49 (1.34–1.67)	1.67 (1.37–2.04)	**0.007**	1.73 (1.58–1.88)	1.75 (1.58–1.95)	1.72 (1.48–2.00)	0.96
Resistin (ng/ml)									
Model 1[c]	3.07 (2.85–3.30)	3.15 (2.86–3.48)	3.34 (3.08–3.64)	3.54 (3.04–4.11)	**0.04**	3.17 (2.96–3.38)	3.26 (3.00–3.54)	3.25 (2.91–3.63)	0.62
Model 2[d]	3.07 (2.84–3.31)	3.14 (2.85–3.47)	3.36 (3.09–3.65)	3.51 (3.02–4.09)	0.053	3.17 (2.96–3.38)	3.24 (2.98–3.52)	3.28 (2.93–3.68)	0.57
Visfatin (ng/ml)									
Model 1[c]	0.92 (0.80–1.05)	0.97 (0.81–1.16)	0.95 (0.81–1.11)	1.07 (0.81–1.41)	0.42	0.90 (0.80–1.02)	1.01 (0.87–1.18)	1.00 (0.81–1.23)	0.29
Model 2[d]	0.96 (0.86–1.08)	0.97 (0.83–1.14)	0.94 (0.82–1.07)	1.06 (0.83–1.34)	0.73	0.92 (0.83–1.03)	1.02 (0.89–1.16)	1.00 (0.84–1.19)	0.26
PAI–1(ng/ml)									
Model 1[c]	31.3 (30.0–32.6)	30.5 (28.9–32.3)	29.5 (28.2–30.9)	28.7 (26.4–31.3)	0.07	30.0 (28.9–31.1)	31.1 (29.7–32.6)	30.1 (28.2–32.0)	0.65
Model 2[d]	31.3 (30.0–32.6)	30.7 (29.1–32.4)	29.6 (28.2–31.0)	28.2 (25.9–30.7)	**0.02**	30.0 (28.9–31.1)	31.1 (29.7–32.5)	30.1 (28.3–32.1)	0.62

Bold values indicate statistical significance

CI confidence interval, *PAI-1* plasminogen activator inhibitor-1

[a] Obtained from multiple linear regression by assigning ordinal numbers 1–4 and 1–3 to increasing categories of coffee and green tea consumption, respectively

[b] Data for adiponectin, resistin and PAI-1. Numbers of subjects for visfatin and leptin were different because those who had outlier values (visfatin) and were not fasting (leptin) were excluded. Numbers were as follows: visfatin: 195, 109, 155 and 47, and 257, 160 and 89 across increasing levels of coffee and green tea consumption, respectively; leptin: 184, 107, 149 and 46, and 244, 158 and 84 across increasing levels of coffee and green tea consumption, respectively

[c] Adjusted for age, sex and workplace

[d] Adjusted for age, sex, workplace, job position, occupational physical activity, non-occupational physical activity, smoking status, alcohol drinking, total energy intake, mutual adjustment for green tea consumption and coffee consumption, hypertension, hyperlipidemia, BMI and use of non-steroid anti-inflammatory drugs

were more likely to be female and tended to use anti-inflammatory drugs. They were less likely to be current smokers and alcohol drinkers. Coffee consumption was inversely, significantly associated with serum leptin and PAI-1 (P for trend = 0.007 and 0.02, respectively) (Table 2). There was a borderline significant positive association between coffee consumption and serum resistin (P for trend = 0.053). Green tea consumption was unrelated to any serum adipokine. As with coffee drinkers, subjects with higher caffeine consumption had significantly lower serum concentrations of leptin and PAI-1 (P for trend = 0.02 for each adipokine) (Table 3). There was a suggestion of positive association between caffeine consumption and adiponectin (P for trend = 0.11) and resistin (P for trend = 0.09), although levels of these adipokines tended to decrease at the highest quartile of caffeine consumption (≥292 mg/day).

In subgroup analyses, we found that serum adiponectin concentrations were progressively higher with increasing coffee consumption in men (P for trend = 0.046), but not in women (P for trend = 0.43), although the interaction by sex was not statistically significant (P for interaction = 0.11)

Table 3 Geometric means (95 % CI) of serum concentrations of adipokines according to quartiles of caffeine consumption

Serum adipokines	Caffeine consumption (mg/d)				
	≤100	101–159	160–291	≥292	P [a] trend
No. of subjects[b]	124	142	123	120	
Adiponectin (μg/ml)					
Model 1[c]	4.37 (3.90–4.90)	5.00 (4.50–5.56)	5.04 (4.49–5.65)	4.90 (4.36–5.51)	0.19
Model 2[d]	4.33 (3.86–4.85)	4.98 (4.49–5.54)	5.03 (4.49–5.64)	4.98 (4.43–5.60)	0.11
Leptin (ng/ml)					
Model 1[c]	1.84 (1.57–2.15)	1.93 (1.67–2.23)	1.58 (1.35–1.84)	1.59 (1.36–1.86)	0.06
Model 2[d]	1.85 (1.64–2.10)	1.93 (1.72–2.16)	1.56 (1.38–1.77)	1.59 (1.40–1.81)	**0.02**
Resistin (ng/ml)					
Model 1[c]	3.05 (2.78–3.35)	3.03 (2.78–3.30)	3.53 (3.21–3.88)	3.29 (2.98–3.62)	0.07
Model 2[d]	3.02 (2.75–3.31)	3.07 (2.82–3.35)	3.55 (3.24–3.91)	3.24 (2.94–3.57)	0.09
Visfatin (ng/ml)					
Model 1[c]	0.89 (0.75–1.06)	0.88 (0.75–1.03)	1.05 (0.88–1.25)	1.02 (0.85–1.21)	0.14
Model 2[d]	0.91 (0.78–1.05)	0.98 (0.85–1.12)	0.98 (0.84–1.13)	1.00 (0.86–1.17)	0.38
PAI-1 (ng/ml)					
Model 1[c]	31.3 (29.7–33.0)	30.7 (29.3–32.3)	29.9 (28.4–31.6)	29.3 (27.8–31.0)	0.07
Model 2[d]	31.5 (29.9–33.2)	31.0 (29.6–32.6)	29.7 (28.2–31.3)	29.0 (27.5–30.7)	**0.02**

Bold values indicate statistical significance

CI confidence interval, *PAI-1* plasminogen activator inhibitor-1

[a] Based on multiple linear regression by assigning ordinal numbers 1–4 to increasing quartiles of caffeine consumption

[b] Data for adiponectin, resistin and PAI-1. Numbers of subjects for visfatin and leptin were different because those who had outlier values (visfatin) and were not fasting (leptin) were excluded. Numbers across increasing quartiles of caffeine consumption were 124, 140, 122 and 120 for visfatin, and the corresponding data for leptin were 116, 135, 119 and 116

[c] Adjusted for age, sex and workplace

[d] Adjusted for age, sex, workplace, job position, occupational physical activity, non-occupational physical activity, smoking status, alcohol drinking, total energy intake, hypertension, hyperlipidemia, BMI and use of non-steroid anti-inflammatory drugs

(Table 4). The inverse association of coffee consumption and serum leptin was evident in men only (P for trend = 0.03), albeit the interaction by sex did not attain statistical significance (P for interaction = 0.67). In addition, we observed a positive association between coffee consumption and serum resistin in men (P for trend = 0.004), but not in women (P for trend = 0.73), and such an association was modified by sex (P for interaction = 0.03). In men, there was a positive association between coffee consumption and resistin in current smokers (P for trend = 0.01), but not in non-smokers (P for trend = 0.35, P for interaction = 0.11). Similar associations were observed for caffeine consumption with regard to analyses stratified by sex, BMI and smoking status in men (Supplemental table). Of note, there was a significant interaction between smoking and coffee for serum resistin concentration in men (P for interaction = 0.04).

Discussion

In the present study, among a working Japanese population, we found inverse associations of coffee and caffeine consumption with serum concentrations of leptin and PAI-1. Although we found no significant association of coffee and caffeine consumption with serum adiponectin in all subjects, we noted a positive association of coffee and caffeine consumption with adiponectin in men, but not in women. Moreover, there was a suggestion of positive association between coffee consumption and resistin in male current smokers. Green tea consumption was not associated with any adipokine. This is one of the few studies addressing the association of coffee and caffeine consumption with adiponectin, leptin and PAI-1 among Asians and is the first investigation to report a positive association with resistin in smoking individuals.

Our findings on the association of coffee and caffeine consumption with serum leptin are consistent with those of some previous studies. A Japanese cross-sectional study of 3317 adults found a significant inverse association between coffee consumption and serum leptin [22]. A small study (n = 48) among healthy elderly Greek men also showed a lower leptin concentration in coffee drinkers consuming ≥2 cups/day than in those drinking <2 cups/day, albeit the difference was not statistically significant [26]. Additionally, a

Table 4 Geometric means (95 % CI)[a] of serum concentrations of adipokines according to coffee consumption stratified by sex, BMI and smoking status (in men only)

Serum adipokines	*n*	Coffee consumption (cup/day)				P_{trend}[b]	$P_{interaction}$[c]
		<1	1	2–3	≥4		
Adiponectin (μg/ml)							
Men	296	3.75 (3.26–4.32)	4.20 (3.51–5.03)	4.39 (3.69–5.21)	4.90 (3.72–6.47)	**0.046**	0.11
Women	213	6.47 (5.46–7.67)	6.40 (5.31–7.71)	6.02 (5.18–6.99)	6.03 (4.67–7.80)	0.43	
BMI < 23 kg/m^2	314	5.01 (4.32–5.81)	5.02 (4.19–6.02)	4.96 (4.13–5.94)	6.36 (4.80–8.43)	0.33	0.82
BMI ≥ 23 kg/m^2	195	4.14 (3.45–4.97)	4.51 (3.62–5.61)	4.64 (3.90–5.52)	4.04 (3.09–5.30)	0.54	
Male non-smoker	177	3.80 (3.09–4.67)	4.72 (3.58–6.22)	4.76 (3.58–6.32)	4.85 (3.02–7.78)	0.12	0.45
Male smoker	119	3.83 (3.14–4.67)	3.69 (2.96–4.60)	4.05 (3.34–4.90)	4.33 (3.25–5.77)	0.42	
Leptin (ng/ml)							
Men	284	1.22 (1.08–1.39)	1.27 (1.08–1.50)	1.02 (0.87–1.18)	1.00 (0.78–1.28)	**0.03**	0.67
Women	202	3.26 (2.60–4.09)	3.02 (2.37–3.85)	2.62 (2.16–3.19)	2.97 (2.14–4.14)	0.17	
BMI < 23 kg/m^2	298	1.41 (1.21–1.64)	1.28 (1.05–1.55)	1.13 (0.95–1.35)	1.16 (0.85–1.56)	0.06	0.59
BMI ≥ 23 kg/m^2	188	3.22 (2.66–3.88)	3.49 (2.76–4.40)	2.27 (1.90–2.71)	2.93 (2.13–4.03)	**0.03**	
Male non-smoker	169	1.22 (1.03–1.44)	1.30 (1.04–1.63)	1.03 (0.82–1.29)	1.17 (0.81–1.70)	0.35	0.20
Male smoker	115	1.33 (1.04–1.70)	1.20 (0.92–1.56)	1.11 (0.88–1.40)	0.88 (0.61–1.25)	0.054	
Resistin (ng/ml)							
Men	296	3.04 (2.74–3.37)	3.00 (2.63–3.42)	3.68 (3.25–4.18)	3.86 (3.15–4.73)	**0.004**	**0.03**
Women	213	3.06 (2.58–3.62)	3.20 (2.65–3.85)	2.89 (2.49–3.36)	3.11 (2.41–4.02)	0.73	
BMI < 23 kg/m^2	314	3.07 (2.74–3.43)	3.33 (2.91–3.82)	3.19 (2.79–3.66)	3.58 (2.89–4.22)	0.23	0.77
BMI ≥ 23 kg/m^2	195	3.16 (2.65–3.77)	2.82 (2.28–3.48)	3.54 (3.00–4.19)	3.49 (2.69–4.52)	0.16	
Male non-smoker	177	2.81 (2.48–3.19)	2.87 (2.42–3.39)	3.13 (2.63–3.73)	2.97 (2.22–3.97)	0.35	0.11
Male smoker	119	3.62 (2.98–4.40)	3.21 (2.59–3.98)	4.65 (3.85–5.60)	5.06 (3.82–6.70)	**0.01**	
PAI-1 (ng/ml)							
Men	296	33.6 (31.8–35.6)	31.7 (29.4–34.0)	31.6 (29.5–33.9)	30.8 (27.6–34.5)	0.08	0.62
Women	213	29.6 (26.8–32.5)	30.9 (27.8–34.4)	28.8 (26.5–31.4)	25.9 (22.4–29.9)	0.19	
BMI < 23 kg/m^2	314	31.1 (29.1–33.1)	30.5 (28.3–33.0)	29.7 (27.5–32.1)	27.8 (24.6–31.4)	0.08	0.46
BMI ≥ 23 kg/m^2	195	32.4 (29.4–35.8)	31.5 (28.0–35.4)	30.0 (27.3–32.9)	29.2 (25.3–33.7)	0.08	
Male non-smoker	177	31.9 (29.8–34.2)	30.3 (27.6–33.2)	30.6 (27.9–33.7)	29.5 (25.2–34.5)	0.27	0.71
Male current smoker	119	38.5 (34.3–43.1)	35.0 (30.8–39.7)	35.4 (31.7–39.5)	35.2 (29.9–41.5)	0.28	

Bold values indicate statistical significance

BMI body mass index, *CI* confidence interval, *PAI-1* plasminogen activator inhibitor-1

[a] Adjusted for age, workplace, job position, occupational physical activity, non-occupational physical activity, alcohol drinking, total energy intake, green tea consumption, hypertension, hyperlipidemia, BMI, use of non-steroid anti-inflammatory drugs and mutual adjustment for sex and current smoking

[b] Based on multiple linear regression analysis by assigning ordinal numbers 1–4 to increasing categories of coffee consumption

[c] Based on likelihood ratio test

Swiss study including 76 subjects during the weight maintenance period disclosed an inverse association between caffeine consumption and circulating leptin [29]. Moreover, regular coffee consumption has consistently been associated with a decreased risk of T2D [3], in which circulating leptin is a good predictor [12]. Contrarily, a study of 5,556 participants in Switzerland found no association between caffeine consumption and plasma leptin [37]. This null association might be ascribed to the effect of potential confounding factors, including smoking, energy intake, hypercholesterolemia and hypertension, all of which were not adjusted in that study. Null effect of coffee ingestion on serum leptin was also shown in a non-randomized clinical trial [18]. A limited number of subjects ($n = 47$) and insufficient intervention period (8 weeks) may overshadow a potentially beneficial effect of coffee on leptin. Our data coupled with previous studies [22, 26, 29] suggest that habitual coffee consumption may be associated with lower blood leptin concentration.

We found a significant positive association of coffee and caffeine consumption with serum adiponectin in men, but not in women. Consistent with our results in men, two previous Japanese studies among men reported a positive

association between coffee consumption and serum adiponectin [19, 23]. A favorable association of coffee consumption with serum adiponectin was also reported in one Japanese study, with a male preponderance (77 %) [22]. Similarly, a Swiss study observed a positive association between caffeine consumption and plasma adiponectin in men, but not in women [37]. However, in another Japanese study among a relatively small number of middle-aged and older men ($n = 205$), regular coffee consumption was not associated with serum adiponectin [24]. As with our null finding in women, two previous investigations found no association between coffee consumption and circulating adiponectin in apparently healthy Japanese women [24] or non-diabetic US female nurses [17]. The reason for the lack of an association in women needs to be addressed in future studies.

We found an inverse association of coffee and caffeine consumption with serum PAI-1. Contrary to our finding, a Finnish study among 60 hypertensive men showed a higher plasma concentration of PAI-1 in individuals consuming >4 cups of coffee/day than in those drinking <1 cup of coffee/day [27]. The result of Finnish study at clinical setting may be more prone to bias than that of the present investigation among apparently healthy participants. Further studies are needed to confirm the effect of high levels of coffee consumption on PAI-1.

Contrary to our hypothesis, coffee consumption was positively associated with serum resistin in male current smokers, but not in male non-smokers in the present study. This observation could be ascribed to chance, but tobacco smoke and some bioactive substances in coffee may work jointly to trigger low-grade inflammation, in which resistin is highly expressed [38], possibly causing resistin augmentation. Given resistin has been shown to predict cardiovascular events [39], the present data may partly explain an increased risk of major cardiovascular diseases associated with coffee consumption among smokers in some studies [40, 41]. Further investigation is required to elucidate the combined effects of smoking and coffee consumption on blood resistin.

Animal studies have shown that oral administration of green tea catechins increased plasma adiponectin levels [42] and improved hypoadiponectinemia [43] and that dietary green tea catechins decreased plasma leptin levels [44]. We thus expected that green tea consumption would be favorably associated with these two adipokines. However, we found no association of green tea consumption with either serum adiponectin or leptin. The null finding for adiponectin is consistent with two previous epidemiological studies reporting no association between green tea consumption and serum adiponectin [19, 25]. Clinical trials also demonstrated that consumptions of green tea and its extract did not change circulating adiponectin [28, 45, 46], neither did they affect plasma leptin [28]. In addition, we observed no association of green tea consumption with resistin, visfatin or PAI-1. In the present study, among a population with relatively high green tea consumption, we confirmed that habitual consumption of this beverage was not associated with blood adipokines. These findings do not support the hypothesis that green tea consumption may play a significant role in determining circulating levels of adipokines. But our study does not deny that green tea may decrease disease risk through mechanisms other than those related to adipokines.

There are several possible mechanisms underlying the association of coffee and caffeine consumption with serum leptin and PAI-1. Leptin is a hormone exclusively secreted by adipocytes, with 80 % total of leptin production come from subcutaneous fat [47]. Coffee is rich in caffeic acid and chlorogenic acid [1], which have been shown to decrease body fat mass and plasma leptin in mice [48]. Similarly, chronic caffeine consumption has been shown to decrease adipose pads weight and the number of adipocytes in rodents [49], thereby decreasing serum leptin concentrations [50]. In addition, regular coffee consumption has been inversely associated with low-grade inflammation [51] and markers of oxidative stress [18], both of which are related to increased leptin [10]. PAI-1 is produced by adipocytes [52], and its increase has been identified as an early marker of endothelial dysfunction [53]. An adiposity-decreasing effect of caffeinated coffee consumption as mentioned above and a beneficial role of decaffeinated coffee consumption in improved endothelial function [51, 54] may be contributed to lowering PAI-1 levels.

Major strengths of the present study include a high response rate (94 %), use of a validated dietary questionnaire, uniform measurements of serum adipokines and adjustment for important confounding factors. Several limitations deserve mention. First, the temporal relationship between coffee or caffeine consumption and adipokines cannot be established by a cross-sectional study. However, our study was conducted among an apparently healthy population, and we excluded underlying chronic diseases including cardiovascular disease, cancer and diabetes. Further, subjects were not aware of their serum adipokine levels when answering the questionnaire. Thus, it is unlikely that serum adipokine status could influence beverage consumption. Second, although coffee and green tea consumption was assessed using a validated, self-administered questionnaire showing a high correlation as compared to 16-d dietary records [33], the real amount of coffee and green tea consumed may be over- or underestimated. In addition, decaffeinated coffee and caffeinated coffee were not distinguished and coffee preparation methods were not specified; however, it is conceivable that decaffeinated or boiled coffee was rarely consumed in Japan. Third, a single-point measurement

of serum adipokines may be subject to within-person variation and prone to the random measurement error. Nevertheless, there was a moderate to high level of intra-individual stability and a low level of seasonal variability of plasma adiponectin, leptin, resistin and PAI-1 [55]. Furthermore, serum visfatin and PAI-1 have shown relatively high CVs (19 and 21 %, respectively) among all of studied adipokines, but these values remain within or are only slightly higher than the desirable range (<20 %) of CVs in reproducibility studies [56]. Fourth, our relatively small sample size may have been underpowered to detect a moderate association, and a limited number of heavy coffee drinkers did not allow us to examine the association at a high level of coffee consumption. Fifth, despite adjustment for important potential confounders, the possibility of residual confounding cannot be ruled out. Finally, the present findings among a working population might not represent the entire adult population.

In conclusion, higher consumption of coffee and caffeine was associated with lower leptin and PAI-1 concentrations (both men and women) and with higher adiponectin concentrations (men only). The protective association of coffee intake with risk of T2D and cancer observed in epidemiologic studies may be partly through the modulation of these adipokines. Prospective investigations are required to confirm the present cross-sectional association, and mechanistic studies should clarify the underlying mechanism behind the association.

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Conflict of interest None.

References

1. Cano-Marquina A, Tarin JJ, Cano A (2013) The impact of coffee on health. Maturitas 75:7–21
2. Cabrera C, Artacho R, Giménez R (2006) Beneficial effects of green tea—a review. J Am Coll Nutr 25:79–99
3. Jiang X, Zhang D, Jiang W (2014) Coffee and caffeine intake and incidence of type 2 diabetes mellitus: a meta-analysis of prospective studies. Eur J Nutr 53:25–38
4. Yu X, Bao Z, Zou J, Dong J (2011) Coffee consumption and risk of cancers: a meta-analysis of cohort studies. BMC Cancer 11:96
5. Yang G, Shu XO, Li H, Chow WH, Ji BT, Zhang X, Gao YT, Zheng W (2007) Prospective cohort study of green tea consumption and colorectal cancer risk in women. Cancer Epidemiol Biomark Prev 16:1219–1223
6. Natella F, Scaccini C (2012) Role of coffee in modulation of diabetes risk. Nutr Rev 70:207–217
7. Thielecke F, Boschmann M (2009) The potential role of green tea catechins in the prevention of the metabolic syndrome—a review. Phytochemistry 70:11–24
8. Nkondjock A (2012) Coffee and cancers. In: Chu Y-F (ed) Coffee: emerging health effects and disease prevention, 1st edn. Wiley, Institute of Food Technologists, Ames, pp 197–209
9. Yang CS, Wang X, Lu G, Picinich SC (2009) Cancer prevention by tea: animal studies, molecular mechanisms and human relevance. Nat Rev Cancer 9:429–439
10. Ouchi N, Parker JL, Lugus JJ, Walsh K (2011) Adipokines in inflammation and metabolic disease. Nat Rev Immunol 11:85–97
11. Li S, Shin HJ, Ding EL, van Dam RM (2009) Adiponectin levels and risk of type 2 diabetes: a systematic review and meta-analysis. JAMA 302:179–188
12. Chen GC, Qin LQ, Ye JK (2014) Leptin levels and risk of type 2 diabetes: gender-specific meta-analysis. Obes Rev 15:134–142
13. van Kruijsdijk RC, van der Wall E, Visseren FL (2009) Obesity and cancer: the role of dysfunctional adipose tissue. Cancer Epidemiol Biomark Prev 18:2569–2578
14. Danese E, Montagnana M, Minicozzi AM, Bonafini S, Ruzzenente O, Gelati M, De Manzoni G, Lippi G, Guidi GC (2012) The role of resistin in colorectal cancer. Clin Chim Acta 413:760–764
15. Huang WS, Chen CN, Sze CI, Teng CC (2013) Visfatin induces stromal cell-derived factor-1 expression by beta1 integrin signaling in colorectal cancer cells. J Cell Physiol 228:1017–1024
16. Gils A, Declerck PJ (2004) Plasminogen activator inhibitor-1. Curr Med Chem 11:2323–2334
17. Williams CJ, Fargnoli JL, Hwang JJ, van Dam RM, Blackburn GL, Hu FB, Mantzoros CS (2008) Coffee consumption is associated with higher plasma adiponectin concentrations in women with or without type 2 diabetes: a prospective cohort study. Diabetes Care 31:504–507
18. Kempf K, Herder C, Erlund I, Kolb H, Martin S, Carstensen M, Koenig W, Sundvall J, Bidel S, Kuha S, Tuomilehto J (2010) Effects of coffee consumption on subclinical inflammation and other risk factors for type 2 diabetes: a clinical trial. Am J Clin Nutr 91:950–957
19. Imatoh T, Tanihara S, Miyazaki M, Momose Y, Uryu Y, Une H (2011) Coffee consumption but not green tea consumption is associated with adiponectin levels in Japanese males. Eur J Nutr 50:279–284
20. Saito M, Nemoto T, Tobimatsu S, Ebata M, Le Y, Nakajima K (2011) Coffee consumption and cystatin-C-based estimated glomerular filtration rates in healthy young adults: results of a clinical trial. J Nutr Metab 2011:146865
21. Wedick NM, Brennan AM, Sun Q, Hu FB, Mantzoros CS, van Dam RM (2011) Effects of caffeinated and decaffeinated coffee on biological risk factors for type 2 diabetes: a randomized controlled trial. Nutr J 10:93
22. Yamashita K, Yatsuya H, Muramatsu T, Toyoshima H, Murohara T, Tamakoshi K (2012) Association of coffee consumption with serum adiponectin, leptin, inflammation and metabolic markers in Japanese workers: a cross-sectional study. Nutr Diabetes 2:e33
23. Mure K, Maeda S, Mukoubayashi C, Mugitani K, Iwane M, Kinoshita F, Mohara O, Takeshita T (2013) Habitual coffee consumption inversely associated with metabolic syndrome-related biomarkers involving adiponectin. Nutrition 29:982–987

24. Kotani K, Fujiwara S, Hamada T, Tsuzaki K, Sakane N et al (2008) Coffee consumption is associated with higher plasma adiponectin concentrations in women with or without type 2 diabetes: response to Williams et al. Diabetes Care 31:e46 (author reply e47)
25. Rebello SA, Chen CH, Naidoo N, Xu W, Lee J, Chia KS, Tai ES, van Dam RM (2011) Coffee and tea consumption in relation to inflammation and basal glucose metabolism in a multi-ethnic Asian population: a cross-sectional study. Nutr J 10:61
26. Lagiou P, Signorello LB, Mantzoros CS, Trichopoulos D, Hsieh CC, Trichopoulou A (1999) Hormonal, lifestyle, and dietary factors in relation to leptin among elderly men. Ann Nutr Metab 43:23–29
27. Tsioufis C, Dimitriadis K, Vasiliadou C, Taxiarchou E, Vezali E, Tsiamis E, Stefanadis C, Kallikazaros I (2006) Heavy coffee consumption in conjunction with smoking is accompanied by increased inflammatory processes and impaired thrombosis/fibrinolysis system in essential hypertensive subjects. J Hum Hypertens 20:470–472
28. Hsu CH, Tsai TH, Kao YH, Hwang KC, Tseng TY, Chou P (2008) Effect of green tea extract on obese women: a randomized, double-blind, placebo-controlled clinical trial. Clin Nutr 27:363–370
29. Westerterp-Plantenga MS, Lejeune MP, Kovacs EM (2005) Body weight loss and weight maintenance in relation to habitual caffeine intake and green tea supplementation. Obes Res 13:1195–1204
30. Andreasson AN, Unden AL, Elofsson S, Brismar K (2012) Leptin and adiponectin: distribution and associations with cardiovascular risk factors in men and women of the general population. Am J Hum Biol 24:595–601
31. Pham NM, Akter S, Kurotani K, Nanri A, Sato M, Hayabuchi H, Yasuda K, Mizoue T (2012) Serum 25-hydroxyvitamin D and markers of insulin resistance in a Japanese working population. Eur J Clin Nutr 66:1323–1328
32. Wu H, Yu Z, Qi Q, Li H, Sun Q, Lin X (2011) Joint analysis of multiple biomarkers for identifying type 2 diabetes in middle-aged and older Chinese: a cross-sectional study. BMJ Open 1:e000191
33. Kobayashi S, Murakami K, Sasaki S, Okubo H, Hirota N, Notsu A, Fukui M, Date C (2011) Comparison of relative validity of food group intakes estimated by comprehensive and brief-type self-administered diet history questionnaires against 16 d dietary records in Japanese adults. Public Health Nutr 14:1200–1211
34. Science and Technology Agency (2005) Standard tables of food composition in japan, 5th revised. Printing Bureau of the Ministry of Finance, Tokyo
35. Ainsworth BE, Haskell WL, Whitt MC, Irwin ML, Swartz AM, Strath SJ, O'Brien WL, Bassett DR Jr, Schmitz KH, Emplaincourt PO, Jacobs DR Jr, Leon AS (2000) Compendium of physical activities: an update of activity codes and MET intensities. Med Sci Sports Exerc 32:S498–S504
36. National Cholesterol Education Program (NCEP) Expert Panel on Detection E, and Treatment of High Blood Cholesterol in Adults (Adult Treatment Panel III) (2002) Third Report of the National Cholesterol Education Program (NCEP) expert panel on detection, evaluation, and treatment of high blood cholesterol in adults (adult treatment panel III) final report. Circulation 106:3143–3421
37. Marques-Vidal P, Bochud M, Paccaud F, Mooser V, Waeber G, Vollenweider P (2010) Distribution of plasma levels of adiponectin and leptin in an adult Caucasian population. Clin Endocrinol (Oxf) 72:38–46
38. Filkova M, Haluzik M, Gay S, Senolt L (2009) The role of resistin as a regulator of inflammation: implications for various human pathologies. Clin Immunol 133:157–170
39. Ding Q, White SP, Ling C, Zhou W (2011) Resistin and cardiovascular disease. Trends Cardiovasc Med 21:20–27
40. D'Avanzo B, La Vecchia C, Tognoni G, Franceschi S, Franzosi MG, Nobili A, Santoro L, Scarsi G (1993) Coffee consumption and risk of acute myocardial infarction in Italian males. GISSI-EFRIM. Gruppo Italiano per lo Studio della Sopravvivenza nell'Infarto, Epidemiologia dei Fattori di Rischio del'Infarto Miocardico. Ann Epidemiol 3:595–604
41. Klatsky AL, Koplik S, Kipp H, Friedman GD (2008) The confounded relation of coffee drinking to coronary artery disease. Am J Cardiol 101:825–827
42. Potenza MA, Marasciulo FL, Tarquinio M, Tiravanti E, Colantuono G, Federici A, Kim JA, Quon MJ, Montagnani M (2007) EGCG, a green tea polyphenol, improves endothelial function and insulin sensitivity, reduces blood pressure, and protects against myocardial I/R injury in SHR. Am J Physiol Endocrinol Metab 292:E1378–E1387
43. Tian C, Ye X, Zhang R, Long J, Ren W, Ding S, Liao D, Jin X, Wu H, Xu S, Ying C (2013) Green tea polyphenols reduced fat deposits in high fat-fed rats via erk1/2-PPARgamma-adiponectin pathway. PLoS One 8:e53796
44. Lee MS, Kim CT, Kim Y (2009) Green tea (−)-epigallocatechin-3-gallate reduces body weight with regulation of multiple genes expression in adipose tissue of diet-induced obese mice. Ann Nutr Metab 54:151–157
45. Ryu OH, Lee J, Lee KW, Kim HY, Seo JA, Kim SG, Kim NH, Baik SH, Choi DS, Choi KM (2006) Effects of green tea consumption on inflammation, insulin resistance and pulse wave velocity in type 2 diabetes patients. Diabetes Res Clin Pract 71:356–358
46. Sone T, Kuriyama S, Nakaya N, Hozawa A, Shimazu T, Nomura K, Rikimaru S, Tsuji I (2011) Randomized controlled trial for an effect of catechin-enriched green tea consumption on adiponectin and cardiovascular disease risk factors. Food Nutr Res 55:8326
47. Antuna-Puente B, Feve B, Fellahi S, Bastard JP (2008) Adipokines: the missing link between insulin resistance and obesity. Diabetes Metab 34:2–11
48. Cho AS, Jeon SM, Kim MJ, Yeo J, Seo KI, Choi MS, Lee MK (2010) Chlorogenic acid exhibits anti-obesity property and improves lipid metabolism in high-fat diet-induced-obese mice. Food Chem Toxicol 48:937–943
49. Greenberg JA, Boozer CN, Geliebter A (2006) Coffee, diabetes, and weight control. Am J Clin Nutr 84:682–693
50. Skurk T, Alberti-Huber C, Herder C, Hauner H (2007) Relationship between adipocyte size and adipokine expression and secretion. J Clin Endocrinol Metab 92:1023–1033
51. Lopez-Garcia E, van Dam RM, Qi L, Hu FB (2006) Coffee consumption and markers of inflammation and endothelial dysfunction in healthy and diabetic women. Am J Clin Nutr 84:888–893
52. Alessi MC, Peiretti F, Morange P, Henry M, Nalbone G, Juhan-Vague I (1997) Production of plasminogen activator inhibitor 1 by human adipose tissue: possible link between visceral fat accumulation and vascular disease. Diabetes 46:860–867
53. Cines DB, Pollak ES, Buck CA, Loscalzo J, Zimmerman GA, McEver RP, Pober JS, Wick TM, Konkle BA, Schwartz BS, Barnathan ES, McCrae KR, Hug BA, Schmidt AM, Stern DM (1998) Endothelial cells in physiology and in the pathophysiology of vascular disorders. Blood 91:3527–3561
54. Buscemi S, Verga S, Batsis JA, Tranchina MR, Belmonte S, Mattina A, Re A, Rizzo R, Cerasola G (2009) Dose-dependent effects of decaffeinated coffee on endothelial function in healthy subjects. Eur J Clin Nutr 63:1200–1205
55. Lee SA, Kallianpur A, Xiang YB, Wen W, Cai Q, Liu D, Fazio S, Linton MF, Zheng W, Shu XO (2007) Intra-individual variation of plasma adipokine levels and utility of single measurement of these biomarkers in population-based studies. Cancer Epidemiol Biomark Prev 16:2464–2470
56. Rosner B (2010) Multisample inference. Fundamentals of biostatistics, 7th edn. Cengage Learning, Boston, pp 516–587