Association of Dietary Inflammatory Potential (DIP) and Endothelial Function Biomarkers among Female Nurses of Isfahan Hospitals

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Research article

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Abstract

Background: Dietary inflammatory index (DIP) is a new dietary index designed to evaluate individuals' diets. In addition, adhesion molecules are important biomarkers for assessing endothelium inflammation that they related to atherosclerosis and cardiovascular disease. Also, there is no study for assessing the association between adhesion molecules and DIP until now as well as other studies that assessed the relationship between dietary inflammatory index or DIP have controversy. The purpose of this cross-sectional study was to determine the correlation between DII and endothelial markers such as E-selectin, intercellular adhesion molecule-1 (sICAM-1) and vascular cell adhesion molecule-1 (sVCAM-1) among female nurses from Isfahan. In this study, dietary inflammatory potential (DIP) was used instead of DII.

Methods: This study was performed on 420 healthy nurses. The nurses were selected by random cluster sampling method from private and public Isfahan hospitals. A validated food frequency questionnaire (FFQ) was applied to assess the dietary inflammatory potential. A fasting blood sample was collected for measuring the plasma levels of the endothelial markers and other variables.

Results: After adjusting different potential confounders, no statistical association was found between DIP and sICAM-1, E–selectin and sVCAM-1 in model I (P=0.57, 0.98 and 0.45), model II (P=0.57, 0.98 and 0.45) and model III (P=0.67, 0.92 and 0.50) in comparison to the crude group (P=0.35, 0.83 and 0.49, respectively).

Conclusions: The results revealed that the plasma levels of endothelial markers including E-selectin, sICAM-1, and sVCAM-1 were not significantly associated with DIP in female nurses.

Introduction

Atherosclerosis is a continuing inflammatory state of the vessels [1]. The progression of atherosclerosis leads to myocardial infarction and sudden death [2]. It is believed that atherosclerosis is an inflammatory condition that is largely responsible for cardiovascular disease (CVD) mortality [3, 4]. Endothelial dysfunction contributes to the pathogenesis of vascular disease and plays an important role in CVD as well [5, 6]. Endothelial dysfunction is characterized by impaired activity of endothelial derived relaxant factors and increased activity of vasoconstrictor factors. However, cell adhesion molecules (CAM) including E-selectin, intercellular adhesion molecule-1 (sICAM-1) and vascular cell adhesion molecule-1 (sVCAM-1) accelerate atherosclerosis [4, 7–9].

Adhesion molecules are normally expressed by the endothelium. They also play a role in leukocyte rolling, firm adhesion, and transmigration. Furthermore, they are associated with a variety of pathophysiological processes and inflammatory disorders. Atherosclerotic lesions and fatty streaks increase the expression of sICAM-1, sVCAM-1, and P- and E-selectin on the human endothelial cells [10, 11]. E-selectin plays an important role in acute inflammation [12–14]. Moreover, sICAM-1 and sVCAM-1 are involved in chronic inflammation [15, 16]. Leukocyte adhesion is an important component of some vascular diseases and atherogenesis. Leukocyte recruitment occurs in a multistep process and selectin, which is expressed on the activated endothelial cells, is involved in the initial rolling process of leukocytes [12, 17]. The leukocyte surface has sites for selectin ligand [18]. β1 and β2 integrin are expressed on leukocytes and act as binding sites for sVCAM-1 or sICAM-1. Furthermore, selectin plays a role in the initial rolling process of leukocytes whereas sICAM-1 and sVCAM-1 mediate leukocyte arresting and firm adhesion [12, 18–20].

Dietary inflammatory potential (DIP) is a new dietary index designed to evaluate the individual's diets. DIP is a tool to assess the potential inflammatory and anti-inflammatory properties of a diet based on food elements. In this index, values of + 1, 0, and − 1 indicate pro-inflammation, indifferent and anti-inflammation reactions, respectively [21]. Actually, DIP is a resource to assess pro-inflammatory effects of food ingredients based on anti-inflammatory functions [21, 22]. DIP has been linked to a variety of systemic biomarkers such as interleukin 6 (IL-6), tumor necrosis factor alpha (TNF-α), C-reactive protein (CRP) and several metabolic diseases such as CVD, cancers, and diabetes. Many studies have found that DIP is associated with the risk of metabolic syndrome and cardiovascular diseases [23–28].

Many studies have reported a positive association between DIP and CVDs [29, 30]. Due to the increase in the global risk of CVDs and related diseases in the world, it is important to find healthy dietary patterns with low inflammatory scores to tackle inflammation and CVDs. The purpose of this study was to determine the association between DIP and endothelial markers such as sICAM, sVCAM, and E-selectin in female nurses working in Isfahan hospitals.

Materials And Methods

Participants

Four hundred and eighty healthy female nurses aged > 30 years participated in this cross-sectional study. The participants were selected randomly from seven public and private hospitals in Isfahan, Iran. The female nurses with a history of diabetes, malignancy, infections, and CVDs were excluded. Furthermore, the subjects who did not complete the FFQ questionnaire were also excluded from the study. Finally, 420 nurses were enrolled in the study. The participants fill in a consent form based on Tehran university of medical sciences ethics rules for participating on this study.

The study protocol was approved by Tehran university of medical sciences (IR.TUMS.VCR.REC.1399.584).

Blood sampling

Blood samples were collected from the participants after 12 hours of fasting to measure the levels of endothelial markers, lipid profile, and fasting blood glucose. Then, the sample were centrifuged for 30–45 minute and frozen at 70°C. The levels of sVCAM- 1, sICAM-1, and E-selectin were measured using commercial ELISA kits (Biosource International and Bender MED Systems) according to the manufacturer’s instructions. ELISA kits were also used to measure low-density lipoprotein (LDL) and high-density lipoprotein (HDL).

Dietary inflammatory score

The method developed by Shivappa *et al* was applied to calculate the DIP scores of the diets. The Food Frequency Questionnaire (FFQ) was used to determine the dietary intake [21]. In the Iranian dietary pattern, 29 out of 45 items of DII are very common, including Macronutrients (energy, carbohydrates, fat, protein, fiber), Fat (cholesterol, saturated fatty acids (SFA), monounsaturated fatty acids (MUFA), polyunsaturated fatty acids (PUFA)), Water-soluble vitamins (pyridoxine, folic acid, niacin, thiamin, ascorbic acid and riboflavin). Fat-soluble vitamins (A,D and E), Minerals (iron, magnesium, zinc, and selenium), as well as caffeine, β-carotene, onion, garlic, pepper, and black tea [31]. Other DIP items that were uncommon in the Iranian dietary regimen were omitted form the list of FFQ.

The intake of the above dietary items was adjusted according to the daily energy intake [32]. A z-score was generated for all of the 29 items of the FFQ list for each participant. For each subject, the "standard global mean" was subtracted from the mean consumed food and divided by “global standard deviation”. The global means and standard deviations were obtained by the method developed by Shivappa *et al* [21]. To decrease the skewness of the variables, the variables were converted to a centered percentile score. This score was then extended by the impact for every item [21]. The DIP scores of all foods were summed to calculate the overall score. More positive values indicated a higher inflammatory dietary potential.

Assessment of other variables

A computerized scale was used for weight measurement (to the nearest 0.1 kg). The subjects were asked to wear light clothing with no shoes. The height was also measured on the same visit day. Finally, weight (kg) and height (m) were used to calculate the body mass index (BMI) according to the following formula: weight (kg)/ height (m) ^{2}.

The International Physical Questionnaire was used to evaluate daily physical activity [33, 34] as MET-hour per week. The factors such as education level, family size, and economic status were inquired from all the participants to determine their socioeconomic status. Moreover, covariate data including age, marital status, menopause situation, past medical history, smoking or medication/supplementation history were selfreported by all the participants.

Statistical analysis

The final analysis was performed on 420 individuals. Energy adjustment of the variables was carried out using the residual method. After completing the FFQ, the data were entered into an Excel datasheet and daily dietary intakes were compared using the IBM SPSS version 26 (IBM SPSS Statistics for Win, Armonk, NY) and Nutritionist IV (N4) software. Since there were three DIP groups (tertiles), one-way ANOVA was used for continuous variables including age, body mass index (BMI), weight, waist circumference, physical activity, and systolic and diastolic blood pressure, and Pearson’s chi-square test was applied to categorical variables such as oral contraceptive (OCP) use, current corticosteroid use, menopause, marital status, overweight/obesity and socioeconomic status. Similarities between the energy intakes of the participants were adjusted by linear regression. Finally, the associations between DIP and E-selectin, ICAM, and VCAM in three tertiles was analyzed using ANCOVA.

Results

The mean ± SD age of the participants was 34.44 ± 7.27, 34.59 ± 6.8 and 36.47 ± 7.4 years in the 1st, 2nd, and 3rd tertile, respectively. The demographic characteristics of the subjects are presented in Table 1.

Table 1
characteristics of participants by tertiles of dietary inflammatory index intake (means ± SD)

Variables	Tertiles of energy by DIP			P-value[a]
	T1 = 133	T2 = 134	T3 = 129	
Age(years)	36.47 ± 7.4	34.59 ± 6.8	34.44 ± 7.27	0.04
Weight(kg)	63.0 ± 8.7	69.2 ± 82.7	63.2 ± 10.32	0.49
BMI(kg/m^2)[b]	24.2 ± 3.37	24.0 ± 3.80	23.97 ± 3.65	0.85
WC(CM)	81.02 ± 9.91	80.51 ± 9.83	81.04 ± 10.82	0.89
PA(MET-h/wk)	60 ± 79	78 ± 77	95 ± 101	0.05
SBP[1] (mmHg)	108 ± 1.04	109 ± 1.20	107 ± 1.24	0.24
DBP(mmHg)	71 ± 0.88	70 ± 1.05	68 ± 0.97	0.08
Current OCP use (%)	5.9	7.4	5.9	0.84
Current corticosteroid use(%)	1.5	2.2	0.7	0.67
Menopausal (%)	8.1	4.4	4.4	0.30
Married (%)	71.3	73.5	73.9	0.87
Overweight or obese (%)	37.7	36.9	43	0.55
Socioeconomic status (%)[c]	24.4	34.7	22.3	0.34
High	44.4	40	48.9	
Medium	31.1	25.3	28.7	
Low				

BMI: body mass index, WC: waist circumference, SBP: systolic blood pressure,DBP: diastolic blood pressure, OCP: oral contraceptives

a) Obtained from analysis of variance for continues variables and chi-square for categorical variables.

b) High socioeconomic status was defined based on educational level, income, family size, being owner of the house or renting the house, house area, being owner of the car and number and kind of the car(s), number of bedrooms, and determination of who was in charge of the family.

c) Body mass index ≥ 25

The distribution of the DIP score between tertiles is shown in Table 2. Large differences in DIP scores were observed for fat (P-value:0.04), riboflavin (P-value < 0.001), folic acid (P-value < 0.001), cobalamin (P-value = 0.005), ascorbic acid (P-value < 0.001), vitamin A (P-value < 0.001), beta carotene (P-value <

0.001), zinc (P-value < 0.001), tea (P-value = 0.002), magnesium (P-value < 0.001), onion (P-value < 0.001), fiber (P-value < 0.001), caffeine (P-value = 0.03), SAFA (P-value = 0.02), and cholesterol (P-value < 0.01) between the tertiles.

Table 2
dietary inflammatory index intake of participants after adjusted energy (mean ± SD)

	Tertile of energy –energy adjusted DIP			
Nutrients	**T1(n = 136)**	**T2(n = 137)**	**T3(n = 136)**	P-value
Protein	124 ± 98	135 ± 139	102 ± 99	0.06
Fat	103 ± 17	117 ± 88	102 ± 21	0.04
Carbohydrate	338 ± 59	321 ± 61	335 ± 71	0.06
Thiamin	3 ± 2	5 ± 25	2 ± 2	0.06
Riboflavin	1.8 ± 0.51	1.6 ± 0.39	1.4 ± 0.47	< 0.001
Niacin	18.9 ± 3	18.8 ± 3	18.4 ± 5	0.6
Pyridoxine	2.2 ± 0.6	2.6 ± 8	1.6 ± 0.6	0.21
Folic acid	410 ± 121	304 ± 41	226 ± 54	< 0.001
Cobalamin	4.7 ± 2	5 ± 2	4 ± 2	0.005
Ascorbic acid	281 ± 111	181 ± 50	126 ± 40	< 0.001
Vitamin A	1928 ± 939	1276 ± 302	887 ± 335	< 0.001
Vitamin E	64 ± 16	69 ± 19	65 ± 21	0.06
Beta carotene	1527 ± 897	904 ± 291	582 ± 311	< 0.001
Vitamin D	1.4 ± 1.5	2.2 ± 11	0.9 ± 1.3	0.21
Selenium	0.04 ± 0.16	0.48 ± 5	-0.01 ± 0.17	0.31
Zinc	10 ± 4	10 ± 6	8 ± 4	< 0.001
Iron	22 ± 6	25 ± 49	20 ± 8	0.39
Tea	356 ± 263	324 ± 316	242 ± 220	0.002
Magnesium	326 ± 59	267 ± 35	216 ± 46	< 0.001
Onion	54 ± 34	40 ± 27	29 ± 19	< 0.001
Garlic	1.9 ± 0.17	1.9 ± 0.25	2 ± 0.002	0.13
Fiber	10 ± 3	7 ± 2	5 ± 1	< 0.001
Caffeine	82 ± 57	83 ± 127	59 ± 50	0.03
Pepper	10 ± 7.3	10 ± 8.7	8 ± 8.5	0.26
SAFA	25 ± 8	27 ± 14	23 ± 9	0.02

Tertile of energy –energy adjusted DIP				
PUFA	40 ± 9	46 ± 44	39 ± 11	0.06
MUFA	32 ± 8	47 ± 146	30 ± 9	0.21
CHOL	234 ± 85	263 ± 93	232 ± 99	0.01

The mean ± SD plasma levels of endothelial markers in different tertiles are shown in Table 3. There was no significant association between DIP and E-selectin in the crude model (P-value = 0.35) compared to model I (P-value = 0.57), model II (P-value = 0.57) and model III (P-value = 0.67) after adjusting for potential confounders (Fig. 1).

Table 3
Index of endothelial functions across tertile categories of dietary inflammatory potential.

Tertile of energy- adjusted DIP				
	T1(n = 133)	T2(n = 136)	T3(n = 135)	P for trend[e]
E-selectin (ng/L)				
Crude	81.6 ± 4.5	85.5 ± 4.5	93.7 ± 4.5	0.35
Model I[b]	80 ± 5.6	88 ± 5.3	80 ± 6.0	0.57
Model II[c]	79 ± 5.6	88 ± 5.3	81 ± 6.1	0.57
Model III[d]	79 ± 5.7	88 ± 5.8	82 ± 6.7	0.67
SICAM-1 (mg/L)				
Crude	221 ± 6.68	211 ± 6.63	213 ± 6.65	0.83
Model I	215 ± 10.9	225 ± 10.2	215 ± 11.7	0.98
Model II	215 ± 10.9	225 ± 10.4	215 ± 10.8	0.98
Model III	214 ± 9.5	213 ± 9.6	212 ± 11.1	0.92
SVCAM-1 (mg/L)				
Crude	503 ± 11.76	482 ± 11.63	509 ± 11.67	0.49
Model I	479 ± 23.2	496 ± 21.8	515 ± 25.3	0.45
Model II	478 ± 23.1	490 ± 22.0	516 ± 25.2	0.45
Model III	477 ± 24.3	492 ± 24.8	502 ± 28.9	0.50
a) Values are mean ± SE in the tables and were compute by the use of ANCOVA.				
b) Model I: adjusted for age, energy intake, physical activity (MET-h/wk), current corticoid steroids use (yes or no), current OCP use (yes or no), marital status (categorical), menopausal status (yes or no), systolic blood pressure, diastolic blood pressure, and socioeconomic status (categorical).				
c) Model II: Further adjusted for BMI.				
d) Model III: Further adjusted for blood lipids and glucose.				
e) *p*-Value was calculated from linear regression of adhesion molecules on a categorical variable of dietary in index intake.				

The results showed no significant association between DIP and the plasma level of sICAM-1 in the crude model (P-value: 0.83) compared to model I (P-value: 0.98), model II (P-value: 0.98) and model III (P-value: 0.92) after adjusting for potential confounders (Fig. 2).

In addition, no significant association was found between DIP and the plasma level of sVCAM-1 in the crude model compared to model I (P-value: 0.49), model II (P-value: 0.45) and model III (P-value: 0.50) after adjusting for potential confounders (Fig. 3).

Discussion

No association was observed between dietary inflammatory potential (DIP) and endothelial biomarkers including E-selectin, sVCAM-1 and sICAM-1 in the participants. This dissociation remained significant after adjusting for possible confounders. This is the first study of the association between adhesion molecules and DIP. Other studies assessed the correlation between DIP and cardiovascular disease.

Adhesion of circulating molecules, including E-selectin, sICAM-1 and sVCAM-1, plays an essential role in endothelial dysfunction and atherosclerosis [14, 35–39]. Furthermore, reactive oxygen species (ROS) activate endothelial markers by inducing E-selectin, sICAM-1 and sVCAM-1. It has been reported that sICAM-1 plays an important role as a predictor of CVD [40]. Moreover, the sVCAM-1 expression represents the inflammatory conditions of the vascular walls and predicts fatal coronary artery disease in the future [39, 41]. Plasma levels of endothelial markers such as sE-selectin and sICAM-1 correlate with prognosis [11]. Many studies have assessed the correlation of DIP with CVD.

The results of the present study are consistent with a study by Imran khan *et al* who carried out a cohort study on 1111 subjects to evaluate the relationship between DIP and cardiovascular disease (CVD). The results showed no a significant correlation between DIP and CVD in females while a significant relationship was found in male subjects [42]. Similarly, Gabriela Pocovi-Gerardino *et al* conducted a cross-sectional study on 105 women with a mean age of 45.4 years old and found no significant correlation between the DIP score and CVD markers [43]. A study of 585 women aged 50–55 years old by Linda E. T. Vissers *et al* failed to show any correlation between DIP and CVD, ischemic heart disease, and myocardial infarction (MI) [44]. Furthermore, a prospective case-control study of 100000 participants showed no significant relationship between DII and MI [45].

By contrast, Bondonno *et al* reported that a high DIP score was associated with atherosclerotic vascular disease in women aged over 70 although they did not find any association between DIP and carotid plaque severity [46]. Moreover, Stefanos Tyrovolas *et al* carried out a dose-dependent study to assess the correlation between DIP and CVD risk factors. They found a significant correlation between DIP and CVD risk factors such as diabetes mellitus, obesity, hypertension, and hypercholesterolemia. In addition, the participants with a high DIP score in the 3rd and 4th quartile had at least one CVD risk factor in comparison to the participants in the 1st quartile [47].

It was difficult to sort out consistent results with our findings because many studies were carried out on subjects with unhealthy conditions. Moreover, there were differences between the studies in terms of the sample size. The geographic dietary pattern may also affect the results. Furthermore, many studies did not measure the plasma levels of sICAM-1, sVCAM-1 and E-selectin directly. Therefore, more studies are required to assess the correlation between endothelial markers and the DIP score.

This study had some limitations. For example, it had a cross-sectional design and therefore no conclusions can be made regarding causality. Moreover, there were some unknown confounders including shift time, bias in reporting food items, and difference in the dietary pattern between nurses in private and public hospitals, which could affect the results. Studies with larger sample sizes are required to obtain concrete results.

Conclusion

In summary, the findings suggest that the plasma levels of endothelial markers including E-selectin, ICAM-1 and sVCAM-1 have no significant correlation with dietary inflammatory potential in females.

Abbreviations

sICAM-1
Soluble intercellular adhesion molecule-1; DIP:Dietary inflammatory potential; FFQ:Food frequency questionnaire; CVD:Cardiovascular disease; CAM:Cell adhesion molecules; IL-6:Interleukin 6; TNF-α:Tumor necrosis factor alpha; CRP:C-reactive protein; LDL:Low-density lipoprotein; HDL:High-density lipoprotein; SFA:Saturated fatty acids; MUFA:Monounsaturated fatty acids; PUFA:Polyunsaturated fatty acids; BMI:Body mass index; OCP:Oral contraceptive

Declarations

Acknowledgments:

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Authors' contributions:

The conception and design of the study performed by MG, ES, AS. Analysis and interpretation of data carried out by MG, AE and confirmed by AS. The collecting samples used to by MG, AH, AY, EF and PS. Manuscript wrote by MG, AE and revised by AS.

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Availability of data and materials:

The data collected and analyzed during in current study. All data are available from professor Ahmad Esmaeilzadeh, Ahmad Saedisomeolia on reasonable request.

Declarations:

Ethics approval and consent to participate

The study protocol was approved by Tehran university of medical sciences (IR.TUMS.VCR.REC.1399.584).

Consent for publication

The participants fill in a consent form based on Tehran university of medical sciences ethics rules for participating on this study.

Competing interests:

The authors declare that they have no competing interests

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Figures

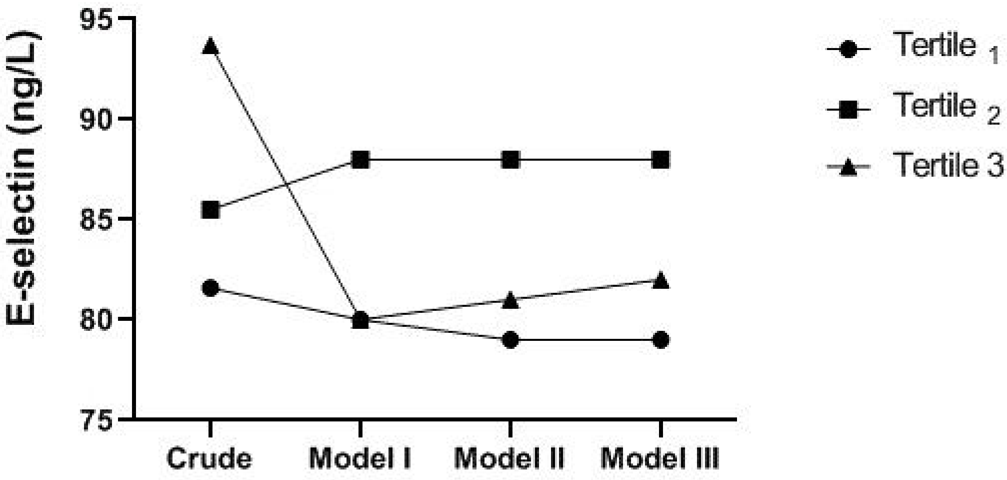

Figure 1

The E-selectin plasma concentration in tertiles (mean±SEM)

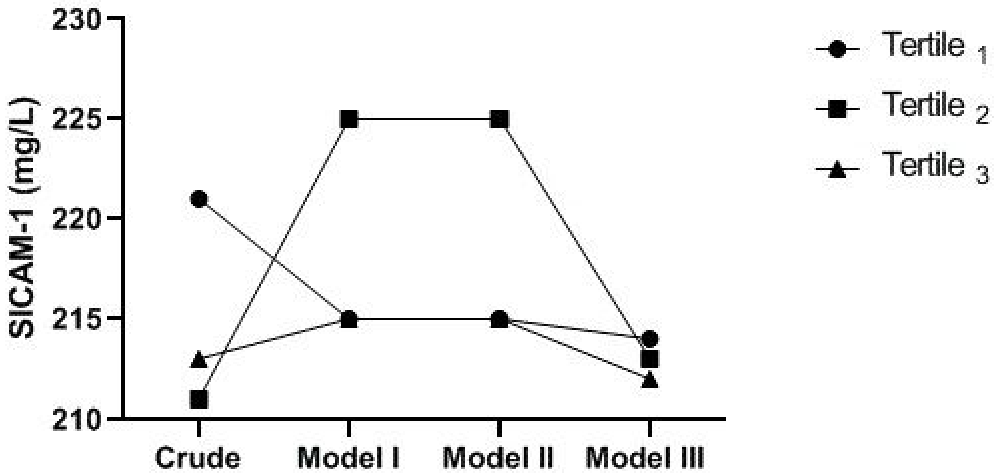

Figure 2

The ICAM-1 plasma concentration in tertiles (mean±SEM)

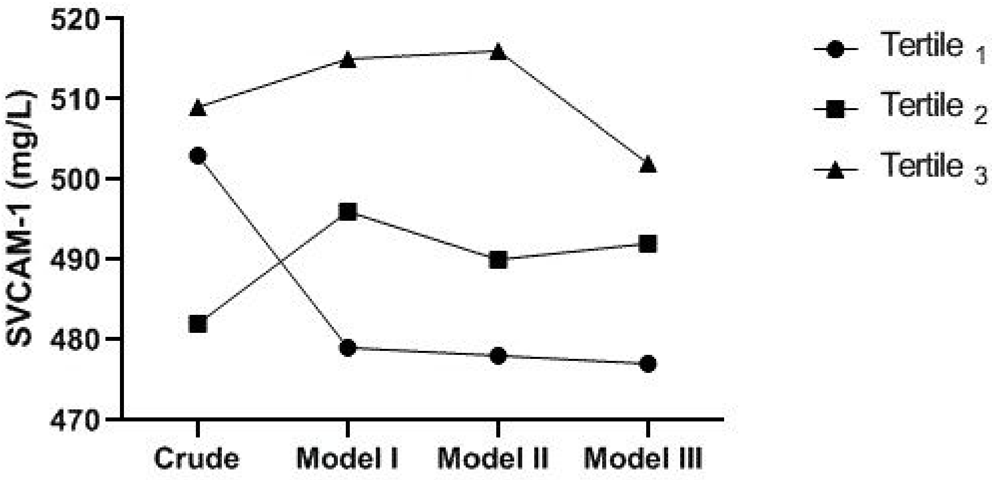

Figure 3

The sVCAM-1 plasma concentration in tertiles (mean±SEM)

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