BMJ Open

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Journal:	*BMJ Open*
Manuscript ID	bmjopen-2018-026148
Article Type:	Research
Date Submitted by the Author:	20-Aug-2018
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Keywords:	PUBLIC HEALTH, EPIDEMIOLOGY, Cigarette Smoking, Blood lipids

Prevalence and associations of behavioral risk factors with blood lipids profile in Lebanese adults: findings from the WHO STEPwise NCD Survey

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Keywords: Cardiovascular disease, cigarette smoking, alcohol consumption, physical inactivity, blood lipids, Lebanon

Word count (excluding title page, references, tables and figures): 2358

Abstract

Objective: To examine associations of behavioral risk factors, including cigarette smoking, physical activity and alcohol consumption, with blood lipids profile.

Design and participants: Data drawn from a cross-sectional study involving participants aged 18 years and over (n = 363) from the national WHO Stepwise Nutrition and Non-communicable Disease Risk Factor survey in Lebanon.

Measures: Demographic characteristics, behaviors and medical history were obtained from participants by questionnaire. Lipid levels were measured by analysis of fasting blood samples (serum total cholesterol (TC), triglycerides (TG), very low-density lipoprotein (VLDL), low-density lipoprotein cholesterol (LDL-C) and high-density lipoprotein cholesterol (HDL-C).

Results: Current cigarette smoking, alcohol consumption and low physical activity were prevalent among 33.3%, 15.4%, and 41.6% of the sample, respectively. Abnormal levels of total cholesterol, triglyceride (TG), very low density lipoprotein (VLDL), low density lipoprotein (LDL-C), and high density lipoprotein were observed for 54.4%, 31.4%, 29.2%, 47.5% and 21.8% of participants, respectively. Adjusting for potential confounders, cigarette smoking was positively associated with higher odds of TG and VLDL (OR=3.82; 95% CI 1.50-9.71; and 4.75; 95% CI 1.10-6.72) with a significant dose-response relationship (p-value for trend=0.019 and 0.039, respectively). Physical activity and alcohol intake did not associate significantly with any blood lipid parameter. **Conclusion**: The demonstrated positive association between smoking and adverse lipoprotein levels in this study population in Lebanon lays further evidence for clinical practitioners, public health professionals and dieticians in the development of preventive strategies among subjects with high risk of CVDs

Strengths and limitations

- A nationwide survey administered in Lebanon with a population distribution similar to that in national records.
- Attention to associations between behavioral factors and intermediary metabolic conditions along the causal pathway for CVD informs work towards development of tailored preventive strategies for high risk individuals.
- Whilst data on smoking and physical activity were sufficiently detailed, measures of exposure to alcohol consumption lacked information on intensity and type, and may be prone to misclassification bias.

Introduction

The prevalence of cardiovascular diseases (CVD) is growing worldwide, and has reached epidemic levels, affecting both developed and developing countries.[1] The Middle East and North Africa (MENA) countries represent a region which is now facing a fast rate of development and urbanization, with rates of chronic diseases increasing at an alarming rate and exceeding at times those of developed countries.[2] In Lebanon, a small middle-income country at the Eastern Mediterranean shore, data from the World Health Organization (WHO) indicate that the proportional mortality from CVD alone is 45%, making it the highest among all non-communicable diseases (NCDs).[3] With a population estimate of around 4.2 million and a Gross Domestic Product (GDP) of 7,315 US Dollars per capita, Lebanon is characterized by a high urbanization rate (87%), a growing trend towards survival in later life, coupled with westernization and modernization in lifestyle and higher uptake of NCD risk factors.[4]

The primary goal in the prevention and management of CVD is to identify and modify the underlying risk behaviors that are amenable to intervention, namely, cigarette smoking, physical inactivity and alcohol consumption. Associations between these factors and CVD risk through their effect on blood lipid levels have been widely examined in the western literature. Studies have shown that smokers are 2-4 times more at risk of developing heart disease than nonsmokers.[5] and the number cigarettes smoked/day independently predicts higher levels of Total Cholesterol (TC), Low Density Lipoprotein-Cholesterol (LDL-C), and Triglycerides (TG).[6] Also, smoking cessation has been shown to improve High Density Lipoprotein-Cholesterol (HDL-C) levels.[7] Cigarette smoking is described as a strong inflammation mediator and a key promoter in the atherosclerotic process. Similarly, the anti-inflammatory effect of frequent physical activity has been noted to be the reason behind reduced heart disease risk among physically active individuals.[8] Regular physical activity

with weight reduction has a large beneficial impact on the lipoproteins profile of adult men and women, [9] by increasing plasma volume, decreasing blood thickness, and thus reducing LDL-C concentrations. [10] Also, systematic reviews and meta-analysis of intervention studies have shown that heavy alcohol drinking results in an elevation in triglyceride levels, while moderate consumption increases circulating levels of HDL-C. [11]

Much of the above evidence comes from studies conducted in North American and European countries and to a lesser extent from the Far East, mostly among Japanese and Korean population. Arab populations including the Lebanese have quite different risk behaviors, varied dietary habits and risk profile, [12] and studies evaluating the association between behaviors and intermediary variables along the causal pathway of CVD including lipid levels remain scarce in the region. Compared with other neighboring countries, Lebanon was shown to have one of the highest prevalence estimates of metabolic syndrome, [13] and has been witnessing high rates of smoking, among both adult men and women aged 18 years and over (42.9% and 27.5%, respectively).[14] Using data from a nation-wide population-based survey of Lebanese adults, this study aims to examine the relation between behavioral risk factors including cigarette smoking, physical activity and alcohol consumption with serum lipids and lipoproteins, while taking into account several potential confounding factors. Findings from this study inform prevention strategies among subjects with high risk of CVD in the country.

Methods

Study design and participants

The data presented in this study are derived from the WHO Nutrition and Non-Communicable Diseases Risk Factor (NNCD-RF) cross-sectional household survey conducted in Lebanon in 2009. [15] Using multi-stage stratified cluster study design, the sampling was based on the age-sex distribution of the Lebanese population as provided by the Central Administration for Statistics. One adult was randomly selected from each household using Kish methodology. [16] Pregnant and lactating women and individuals with mental disabilities were excluded. Survey participants aged 18 years and above and free from known history of hyperlipidemia and diabetes in the first phase of the study (n = 1,331) were approached to undergo a biochemical assessment, of which 363 provided written consent and gave fasting blood samples. Further details on the design and sample of the survey are published elsewhere. [4] The study protocol was approved by the Institutional Review Board of the American University of Beirut (AUB), and informed consent was taken from all participants.

Data collection

The data collection procedure followed the WHO STEPwise approach to Surveillance, [17] and included the following three steps: Step 1 Questionnaire, whereby information about socio-demographic characteristics, NCDs and NCD risk factors were collected through face-to-face interviews; Step 2 in which anthropometric and blood pressure measurements were taken using standardized techniques and calibrated equipment; and finally, Step 3 in which biochemical analysis for assessment of the blood lipid profile was performed on blood samples collected after an overnight fast. Serum was centrifuged on site and shipped on dry ice to the AUB Laboratory.

Measures of blood lipids

Levels of blood lipids including TC, TG, very low density lipoprotein (VLDL), LDL-C and HDL-C were analyzed using the Vitros 350 analyzer, an enzymatic spectrophotometric technique. The inter-assay variation of measurements did not exceed 4%. Quality control was performed within each run using standard performance verifier solutions provided by Ortho-Clinical Diagnostics. Analyses were conducted in duplicates, and the average value was utilized in the analysis. Based on the Adult Treatment Panel III guidelines, [18] the cutoff points used for the definition of risk levels of TC, TG, VLDL, LDL-C and HDL-C were ≥200, ≥150, ≥30, ≥130 and ≤40 mg/dl, respectively.

Behavioral risk factors and other measures

Behavioral risk factors examined in this study included cigarette smoking, physical activity, and alcohol consumption. Cigarette smoking status (never, past and current) and intensity (number of cigarettes smoked/day) were assessed. Intensity was later categorized into three levels according to number of cigarettes/day (1 to 19, 20 to 39 and ≥40). The short version of the International Physical Activity Questionnaire was used to assess physical activity among participants. [19] Three categories of physical activity (low, moderate, and high) were assigned based on METs-min/week (MET-min being the product of the resting metabolic rate for an activity and the number of minutes taken to perform it). Alcohol consumption was assessed as a dichotomous variable (yes/no) based on consumption of at least 1 drink/week in the year prior to the survey. Covariates of interest included total daily caloric intake, which was estimated based on the food frequency questionnaire and divided into tertiles. In addition, gender, age (18-29, 30-39, 40-49, 50-59, and ≥60), marital status (single, married, divorced/widowed), education level (complementary or less, secondary/technical, university and above), and occupational status (student/volunteer, working, does not work/housewife/retired) were considered as potential covariates.

Patient and Public Involvement

This study is based on secondary data analyses. The original data collection tool was adapted from the WHO STEPwise approach to NCD risk factor surveillance,[17] that did not directly involve patients or the public in outcome development or conduct of the study. However, we are engaging with stakeholders to disseminate the findings on the burden of tobacco consumption and its association with various health-related outcomes to the public at large.

Statistical analysis

Means, standard deviations (SD) and frequencies were used to describe the various socio-demographic, behavioral, nutritional and clinical characteristics of the participants. The associations between each of the three behavioral risk factors and levels of the different blood lipids were examined using multiple logistic regression analysis. Unadjusted and adjusted odds ratios (ORs) and their 95% confidence intervals (CIs) controlling for age, gender, education, marital status and caloric intake were estimated. Test for trend with increasing number of daily amount of cigarette smoked was also conducted, and a two-sided p-value < 0.05 was considered significant. The Statistical Package for the Social Sciences 22.0.1 (SPSS Inc., Chicago, IL, USA) was used for all computations.

Results

The socio-demographic and health-related characteristics of the study sample are summarized in Table 1. The sample was equally divided by gender (49.9% females and 50.1% males), with a mean age of 39.2 ± 15.2 years (range 18 to 92 years). The majority were married (60.6%), and close to half of the participants were employed (52.3%) at the time of the study, with an almost equal distribution across the various educational levels. Ever smokers constituted 37.4% of the sample. 41.6% were classified as being engaged in low-intensity

physical activity, and 15.4% reported current alcohol consumption at least once per week. The sample consumed 2656 ± 1249 Kcal/day on average. Abnormal levels of TC, TG, VLDL, LDL-C, and HDL-C were observed for 55.4%, 31.4%, 29.2%, 47.5% and 21.8% of the participants, respectively.

Insert table 1 around here

Tables 2a and 2b show the unadjusted and adjusted ORs for the association between behavioral risk factors and blood lipids levels. Out of all the relationships examined, only cigarette smoking showed a significant association with blood lipids. Associations were significant for those consuming more than 40 cigarette/day compared to non-smokers, with unadjusted ORs of 5.03 for TG, 4.09 for VLDL and 3.02 for HDL-C. Adjusting for potential confounders, the associations maintained statistical significance for TG and VLDL, with an adjusted OR 3.82 (95% CI 1.50- 9.71) and 4.75 (95% CI 1.10-6.72), respectively. Results showed a dose-response relationship with increasing number of cigarettes consumed for (p-value for trend = 0.019 and 0.039, respectively). Physical activity and alcohol intake were not associated with any of the blood lipid parameters.

Insert tables 2a and 2b around here

Discussion

Our results showed that heavy cigarette smoking exceeding 40 cigarettes/day is associated with increased levels of TG and VLDL, with findings showing significant dose-response relationships with increasing number of cigarettes smoked per day. However, there were no consistent associations between physical activity and alcohol consumption with fasting blood

lipids profile. To our knowledge, this is the first study in Lebanon to explore these associations, based on objectively measured lipid parameters and using standardized laboratory techniques and tools, while taking into consideration the effect of potential confounders.

There are strong indicators in the literature that the deleterious effect of cigarette smoking on heart disease and atherosclerosis is partially explained by the effect of smoking on the concentration of blood lipids and lipoproteins. Our study confirms the results of earlier cross-sectional studies showing that the association between smoking and lipoproteins are observed in the levels of TG, VLDL and HDL-C, [6, 20, 21] with the impact on lipid levels increasing with increase in the number of cigarettes smoked/day in a dose dependent relationship. [22, 23] Our observation of the largest effect of cigarette smoking on lipid parameters being seen in those who smoked > 40 cigarettes/day is also consistent with Chen et al. study comprising of 1,164 men in Taiwan. [24] One popular mechanism by which smoking affects lipoproteins is that cigarette particulate matter alters catecholamine release—and thus free fatty acid release, which in turn contributes to the accumulation of the LDL-C concentrations and to lower levels of HDL-C in the blood. [25] The association between cigarette smoking and the increase in TG can also be explained by the decrease in the activity of the lipoprotein lipase among smokers thus disrupting lipid and lipoprotein metabolism. Furthermore, smoking cessation was found to improve lipid and lipoprotein levels in observational studies and randomized clinical trials. [7, 26] Taken together, the totality of evidence from these studies and our data-including consistency upon replication across various studies, the dose-response relationship, the magnitude and significance of association, biological plausibility as well as effects of smoking cessation on lipoprotein levels, supports a strong relationship between smoking and lipid profiles.

In our study, physical activity and alcohol consumption did not appear to be associated with lipid parameters. The literature suggests that physical activity increases the level of HDL-C and has beneficial effects on lipoprotein particle size and number. [27] Also, moderate intensity exercise is known to have a more favorable effect on blood lipids since it allows the use of lipids as a fuel source which implies an increase in the uptake and oxidation of the lipids in the skeletal muscle. [27] As for the relationship between alcohol consumption and lipid parameters in the general population, findings have been less consistent in the literature, with some but not all showing an effect on higher HDL-C levels and lower non-HDL-C levels. [28,29] Indeed, the effect of alcohol on CVD including coronary artery disease, stroke and myocardial infarction appears to be biphasic showing a J or U-shaped relationship based on the amount of alcohol consumed, [29,30] with lower CVD mortality risks by light to moderate alcohol consumption and increased risk by heavy alcohol intake. [31] The discrepancy between our results with those in the literature may be due to differences in race/ethnicity and genetic variations known to play a significant role in lipid metabolism,[32] or alternatively, owing to measurement error in our assessment of alcohol consumption, based on self-reports of a dichotomous variable. Lipid profiles are influenced by the type of alcohol consumed and by drinking frequency and patterns.

Some other limitations should be taken into consideration when analyzing the results of our study. Because the study used a cross-sectional design, the results only imply associations and findings cannot establish causal relationships. The number of participants who agreed to give blood samples was relatively small; however, theses responders were comparable to non-responders on a number of socio-demographic characteristics except for marital status (61% of responders vs. 50% of non-responders were married). As mentioned earlier, measures of exposure were self-reported which can introduce some misclassification error. Whilst this may have been problematic in case of alcohol consumption that lacked detailed

data on intensity and type, measurement of cigarette smoking and physical activity were more detailed and reliable. Information on cigarette smoking in our study included the amount of cigarettes smoked and the standardized IPAQ was used to assess physical activity.

To conclude, our results suggest that smoking is associated with adverse levels of lipoprotein, notably TGs and VLDL among Lebanese men and women. The role of lipoproteins in atherogenesis has been clearly defined, and controlling for blood lipid levels decreases the risk of heart and many other chronic diseases. Our findings lay further evidence for clinical practitioners, public health professionals and dieticians regarding the potential benefits of smoking cessation in their pursuit to curb the burden of hyperlipidemia and CVD at the individual and population level. The overall high rate of smoking behavior in Lebanon among both men and women, coupled with lack of dedicated funds and weak implementing power for the enforcement of the tobacco control law, are likely to adversely impact on the healthcare bill in the country. Further studies with larger sample size that examine the association of combination patterns of poor lifestyle factors on lipid profile among Lebanese adults are warranted.

Contributors
AMS conceived the study. MM did the analyses and wrote first draft of the paper. HT and AMS supervised the conduct of analyses and contributed substantially to the write-up of the paper. CK, NH, MC and AF provided statistical advice and contributed to the paper revision. All authors read and approved the final manuscript.

Funding statement
The original study conduct was funded by the World Health Organization (WHO) - Lebanon.

Data sharing statement
The database set was available for all authors of the study, and will be available for other non-commercial researchers on request.

Declaration of conflicting interests
The authors declare that there is no conflict of interest.

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Table 1 Socio-demographic and health-related characteristics of the study population.

	n	%
Gender (% female)	181	49.9
Age (mean ± SD, years)	39.2 ± 15.2	
18-29	113	31.1
30-39	106	29.2
40-49	67	18.5
50-59	32	8.8
≥60	45	12.4
Marital Status		
Single	128	35.3
Married	220	60.6
Divorced/widowed	15	4.1
Work Status		
Student or volunteer	31	8.5
Employed	190	52.3
Does not work/housewife/retired	142	39.1
Educational Level		
Complementary or less	144	39.7
Secondary or technical	99	27.3
University and above	120	33.1
Cigarette Smoking		
Never smoked	227	62.5
Past smoker	15	4.1
Current smoker	121	33.3
Number of cigarettes smoked/day		
0	227	62.5
1-19	43	11.8
20-39	63	17.4
≥40	30	8.3
Physical activity		
Low-intensity activity	151	41.6
Moderate-intensity activity	121	33.3
High-intensity activity	88	24.2
Alcohol consumption (≥ once/week)	56	15.4
Total caloric intake (mean ± SD, Kcal/day)	2656 ± 1249	
Total Cholesterol (mean ± SD, mg/dl)	210 ± 45	
% Elevated total cholesterol	201	55.4
Triglycerides (mean ± SD, mg/dl)	138 ± 78	
% Elevated triglycerides	114	31.4
VLDL* (mean ± SD, mg/dl)	27 ± 15	
% Elevated VLDL	106	29.2
LDL-C* (mean ± SD, mg/dl)	131 ± 39	
% Elevated LDL-C	172	47.5
HDL-C* (mean ± SD, mg/dl)	51 ± 14	
% Reduced HDL-C	79	21.8

*Very Low Density Lipoprotein (VLDL); Low Density Lipoprotein cholesterol (LDL-C); High Density Lipoprotein cholesterol (HDL-C)

Table 2a Logistic regression analysis: associations of behavioral risks with total cholesterol (TC) and triglycerides (TG)

		TC			TG		
		% ≥200 mg/dl	Crude OR (CI)	Adjusted* OR (CI)	% ≥150 mg/dl	Crude OR (CI)	Adjusted* OR (CI)
Number of Cigarettes	0	52.0	1.00	1.00	25.6	1.00	1.00
	1-19	55.8	1.17 (0.60-2.25)	0.77 (0.35-1.67)	30.2	1.26 (0.62-2.58)	1.00 (0.44-2.26)
	20-35	63.5	1.60 (0.90-2.85)	1.03 (0.51-2.07)	38.1	1.79 (0.99-3.23)	1.25 (0.64-2.46)
	≥40	63.3	1.59 (0.73-3.50)	1.08 (0.41-2.84)	63.3	5.03 (2.26-11.2)	3.82 (1.50-9.71)
	p-trend		0.070	0.916		<0.001	0.019
Physical activity	High	55.7	1.00		25.0	1.00	
	Moderate	56.2	1.02 (0.59-1.77)	0.85 (0.45- 1.63)	32.2	1.43 (0.77-2.64)	1.34 (0.67-2.66)
	Low	55.6	0.99 (0.59-1.69)	0.97 (0.52-1.78)	35.1	1.62 (0.90-2.92)	1.42 (0.75-2.68)
Alcohol intake	No	54.7	1.00	1.00	30.6	1.00	1.00
	Yes	58.9	1.19 (0.67-2.12)	1.37 (0.67-2.77)	35.7	1.26 (0.69-2.29)	1.05 (0.52-2.10)

*Controlling for age, gender, education, marital status and caloric intake.

Table 2b Logistic regression analysis: associations of behavioral risks with very low-density lipoprotein (VLDL), low-density lipoprotein cholesterol (LDL-C) and high-density lipoprotein cholesterol (HDL-C).

		VLDL			LDL-C			HDL-C		
		%≥30 mg/dl	Crude OR (CI)	Adjusted* OR (CI)	%≥130 mg/dl	Crude OR (CI)	Adjusted* OR (CI)	%<40 mg/dl	Crude OR (CI)	Adjusted* OR (CI)
Number of Cigarettes	0	24.2	1.00		43.6	1.00		18.1	1.00	
	1-19	27.9	1.21 (0.58-2.52)	0.96 (0.41-2.20)	53.5	1.49 (0.77-2.86)	1.09 (0.51-2.34)	18.6	1.04 (0.45-2.40)	0.94 (0.35-2.54)
	20-39	35.5	1.72 (0.94-3.14)	1.21 (0.61-2.42)	54.8	1.57 (0.89-2.76)	1.00 (0.51-1.97)	28.6	1.81 (0.95-3.45)	1.67 (0.77-3.63)
	≥40	56.7	4.09 (1.87-8.95)	4.75 (1.10-6.72)	53.3	1.48 (0.69-3.17)	1.78 (0.37-2.37)	40.0	3.02 (1.35-6.76)	1.61 (0.62-4.24)
	p-trend		<0.001	0.039		0.083	0.688		0.003	0.745
Physical activity	High	26.1	1.00		48.9	1.00		27.3	1.00	
	Moderate	28.9	1.15 (0.62-2.13)	1.00 (0.50-1.99)	49.6	1.02 (0.59-1.78)	0.87 (0.46-1.64)	19.0	0.62 (0.32-1.20)	0.78 (0.36-1.68)
	Low	32.0	1.33 (0.74-2.39)	1.11 (0.59-2.09)	46.0	0.89 (0.53-1.51)	0.85 (0.47-1.53)	21.2	0.72 (0.40-1.32)	0.62 (0.31-1.25)
Alcohol Intake	No	28.7	1.00		46.6	1.00		21.2	1.00	
	Yes	32.7	1.21 (0.65-2.24)	0.93 (0.46-1.90)	52.7	1.28 (0.72-2.27)	1.36 (0.68-2.73)	25.0	1.24 (0.64-2.41)	0.75 (0.35-1.61)

*Controlling for age, gender, education, marital status and caloric intake.

BMJ Open

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Journal:	*BMJ Open*
Manuscript ID	bmjopen-2018-026148.R1
Article Type:	Research
Date Submitted by the Author:	07-Mar-2019
Complete List of Authors:	Mansour, Megali; American University of Beirut Faculty of Health Sciences, EPHD Tamim, Hani; American University of Beirut, Biostatistics Unit, Clinical Research Institute Nasreddine, Lara; American University of Beirut EL Khoury, Christelle; Tufts University School of Medicine Hwalla, Nahla; American University of Beirut Chaaya, Monique; American University of Beirut Farhat, Antoine ; Notre Dame University Sibai, Abla; American University of Beirut, EPHD
Primary Subject Heading:	Public health
Secondary Subject Heading:	Epidemiology, Nutrition and metabolism, Smoking and tobacco, Public health
Keywords:	PUBLIC HEALTH, EPIDEMIOLOGY, Cigarette Smoking, Blood lipids

Prevalence and associations of behavioral risk factors with blood lipids profile in Lebanese adults: findings from the WHO STEPwise NCD Survey

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Keywords: Cardiovascular disease, smoking, alcohol consumption, physical inactivity, dietary intake, blood lipids, Lebanon

Word count (excluding title page, references, tables and figures): 3047

Abstract

Objective: To examine associations of behavioral risk factors, namely cigarette smoking, physical activity, dietary intakes and alcohol consumption, with blood lipids profile.

Design and participants: Data drawn from a cross-sectional study involving participants aged 18 years and over (n = 363) from the nationwide WHO Stepwise Nutrition and Non-communicable Disease Risk Factor survey in Lebanon.

Measures: Demographic characteristics, behaviors and medical history were obtained from participants by questionnaire. Dietary assessment was performed using a 61-item culture-specific food frequency questionnaire that measured food intake over the past year. Lipid levels were measured by analysis of fasting blood samples (serum total cholesterol (TC), triglycerides (TG), very low-density lipoprotein (VLDL), low-density lipoprotein cholesterol (LDL-C) and high-density lipoprotein cholesterol (HDL-C).

Results: Current cigarette smoking, alcohol consumption and low physical activity were prevalent among 33.3%, 39.7%, and 41.6% of the sample, respectively. The contributions of fat and saturated fat to daily energy intake were high, estimated at 36.5% and 11.4%, respectively. Abnormal levels of TC, TG, VLDL, LDL-C, and HDL-C were observed for 55.4%, 31.4%, 29.2%, 47.5% and 21.8% of participants, respectively. Adjusting for potential confounders, cigarette smoking was positively associated with higher odds of TG and VLDL (OR=4.27; 95% CI 1.69-10.77; and 3.26; 95% CI 1.33-8.03) with a significant dose-response relationship (p-value for trend=0.010 and 0.030, respectively). Alcohol drinking and high saturated fat intake (≥10% energy intake) were associated with higher odds of LDL-C (OR=1.68; 95% CI: 1.01-2.82 and OR= 1.73; 95% CI: 1.02-2.93). Physical activity did not associate significantly with any blood lipid parameter.

Conclusion: The demonstrated positive association between smoking, alcohol drinking and high saturated fat intake with adverse lipoprotein levels lays further evidence for clinical

practitioners, public health professionals and dietitians in the development of preventive strategies among subjects with high risk of CVDs in Lebanon.

Strengths and limitations

- A nationwide survey administered in Lebanon, following the WHO STEPwise approach to surveillance guidelines, thus allowing for comparison with international literature.
- Low response rate (27.3%) for those who consented and gave fasting blood samples. Yet, differences between responders and non-responders were not significant on a number of socio-demographic characteristics.
- Whilst data on smoking, physical activity and dietary intakes were sufficiently detailed, measures of exposure to alcohol consumption lacked information on intensity and type, and may be prone to misclassification bias.
- Attention to associations between behavioral factors and dietary intakes with intermediary metabolic conditions along the causal pathway for CVD informs work towards development of tailored preventive strategies for high risk individuals.

Introduction

The prevalence of cardiovascular diseases (CVD) is growing worldwide, and has reached epidemic levels, affecting both developed and developing countries.[1] The Middle East and North Africa countries represent a region which is now facing a fast rate of development and urbanization, with rates of chronic diseases increasing at an alarming rate and exceeding at times those of developed countries.[2] In Lebanon, a small middle-income country at the Eastern Mediterranean shore, data from the World Health Organization (WHO) indicate that the proportional mortality from CVD alone is 45%, making it the highest among all non-communicable diseases (NCDs).[3] With a population estimate of around 4.2 million and a Gross Domestic Product (GDP) of close to 8,520 US Dollars per capita, Lebanon is characterized by a high urbanization rate (87%), a growing trend towards survival in later life, coupled with westernization and modernization in diet and lifestyle and higher uptake of NCD risk factors.[4]

The primary goal in the prevention and management of CVD is to identify and modify the underlying risk behaviors that are amenable to intervention, namely, cigarette smoking, physical inactivity, dietary intakes and alcohol consumption. Associations between these factors and CVD risk through their effect on blood lipid levels have been widely examined in the western literature. Studies have shown that smokers are 2-4 times more at risk of developing heart disease than nonsmokers[5] and the number of cigarettes smoked/day independently predicts higher levels of Total Cholesterol (TC), Low Density Lipoprotein-Cholesterol (LDL-C), and Triglycerides (TG).[6] Also, smoking cessation has been shown to improve High Density Lipoprotein-Cholesterol (HDL-C) levels.[7] Cigarette smoking is described as a strong inflammation mediator and a key promoter in the atherosclerotic process. Similarly, the anti-inflammatory effect of frequent physical activity has been noted to be the reason behind reduced heart disease risk among physically active individuals.[8]

Regular physical activity with weight reduction has a large beneficial impact on the lipoproteins profile of adult men and women, [9] by increasing plasma volume, decreasing blood thickness, and thus reducing LDL-C concentrations. [10] Also, systematic reviews and meta-analysis of intervention studies have shown that heavy alcohol drinking results in an elevation in triglyceride levels, while moderate consumption increases circulating levels of HDL-C. [11] Similarly, diet is recognized as a modifiable risk factor that can make a substantial contribution to the risk of CVD. [12 13] Energy intake, the types of fatty acids consumed and the level of sugar ingestion may impact the lipid and cardiometabolic profile.[14] The 2017 Presidential Advisory from the American Heart Association indicated that replacement of saturated fat with unsaturated fatty acids decreases LDL-C levels and CVD risk, while replacing it with refined carbohydrates and sugar, yields no significant benefits to cardiovascular health. [14]

Much of the above evidence comes from studies conducted in North American and European countries and to a lesser extent from the Far East, mostly among Japanese and Korean population. Arab populations including the Lebanese have quite different risk behaviors, varied dietary habits and risk profile, [15] and studies evaluating the association between behaviors and intermediary variables along the causal pathway of CVD including lipid levels remain scarce in the region. Compared with other neighboring countries, Lebanon was shown to have one of the highest prevalence estimates of metabolic syndrome, [16] and has been witnessing high rates of smoking, among both adult men and women aged 18 years and over (42.9% and 27.5%, respectively).[17] Using data from a nationwide population-based survey of Lebanese adults, this study aims to examine the relation between behavioral risk factors including cigarette smoking, physical activity, dietary intakes and alcohol consumption with serum lipids and lipoproteins, while taking into account several potential confounding factors. Findings

from this study inform prevention strategies among subjects with high risk of CVD in the country.

Methods

Study design and participants

The data presented in this study are derived from the WHO Nutrition and Non-Communicable Diseases Risk Factor (NNCD-RF) cross-sectional household survey conducted in Lebanon in 2009. [18] Using multi-stage stratified cluster study design, the sampling was based on the age-sex distribution of the Lebanese population as provided by the Central Administration for Statistics. One adult was randomly selected from each household using Kish methodology. [19] Pregnant and lactating women and individuals with mental disabilities were excluded. With a non-response rate of 10% at the individual level, this yielded a sample of 2668 survey participants aged 18 years and above. Those free from known history of hyperlipidemia and diabetes in the first phase of the study (n = 1,331) were approached to undergo a biochemical assessment, of which 363 provided written consent and gave fasting blood samples. Further details on the design and sample of the survey are published elsewhere. [4] The study protocol was approved by the Institutional Review Board of the American University of Beirut (AUB), and informed consent was taken from all participants.

Data collection

The data collection procedure followed the WHO STEPwise approach to Surveillance, [20] and included the following three steps: Step 1 Questionnaire, whereby information about socio-demographic characteristics, NCDs and NCD risk factors, including dietary intake, were collected through face-to-face interviews; Step 2 in which anthropometric and blood pressure

measurements were taken using standardized techniques and calibrated equipment; and finally, Step 3 in which biochemical analysis for assessment of the blood lipid profile was performed on blood samples collected after an overnight fast of at least 8 hours. Serum was centrifuged on site and shipped on dry ice to the AUB Laboratory.

Measures of blood lipids

Levels of blood lipids including TC, TG, very low density lipoprotein (VLDL), LDL-C and HDL-C were analyzed using the Vitros 350 analyzer, an enzymatic spectrophotometric technique. The inter-assay variation of measurements did not exceed 4%. Quality control was performed within each run using standard performance verifier solutions provided by Ortho-Clinical Diagnostics. Analyses were conducted in duplicates, and the average value was utilized in the analysis. Based on the Adult Treatment Panel III guidelines, [21] the cutoff points used for the definition of risk levels of TC, TG, VLDL, LDL-C and HDL-C were ≥200, ≥150, ≥30, ≥130 and ≤40 mg/dl, respectively.

Behavioral risk factors and other measures

Behavioral risk factors examined in this study included cigarette smoking, physical activity, and alcohol consumption. Cigarette smoking status (never, past and current) and intensity (number of cigarettes smoked/day) were assessed. Intensity was later categorized into three levels according to number of cigarettes/day (1 to 19, 20 to 39 and ≥40). The short version of the International Physical Activity Questionnaire was used to assess physical activity among participants. [22] Three categories of physical activity (low, moderate, and high) were assigned based on METs-min/week (MET-min being the product of the resting metabolic rate for an activity and the number of minutes taken to perform it). Alcohol-related behavior was assessed as a dichotomous variable (ever vs never). Dietary assessment was performed using

a 61-item culture-specific food frequency questionnaire that measured food intake over the past year. [4, 15] Intakes of energy and macronutrients were estimated using the food composition database of the Nutritionist IV software, and the food composition table for local and traditional Middle-Eastern foods. [23,24] Intakes of carbohydrates, fat and protein were compared to cut-offs within the Acceptable Macronutrient Distribution Range, [25] and intakes of saturated fat and sugar were compared to the recommendations of the WHO. [26, 27]

Covariates of interest included total daily caloric intake and body mass index (BMI), measured as the ratio of weight (kilograms) to the square of height (meters). In addition, gender, age (18-29, 30-39, 40-49, 50-59, and ≥60), marital status (single, married, divorced/widowed), education level (complementary or less, secondary/technical, university and above), and occupational status (student/volunteer, working, does not work/housewife/retired) were considered as potential covariates.

Patient and Public Involvement

This study is based on secondary data analyses. The original data collection tool was adapted from the WHO STEPwise approach to NCD risk factor surveillance, [20] that did not directly involve patients or the public in outcome development or conduct of the study. However, we have been engaging with stakeholders to disseminate the findings on NCD risk factors, including tobacco consumption and dietary intakes, and on associations with various health-related outcomes to the public at large.

Statistical analysis

Means, standard deviations (SD) and frequencies were used to describe the various socio-demographic, behavioral, nutritional and clinical characteristics of the participants. The

associations between each of the risk factors and levels of the different blood lipids were examined using multiple logistic regression analysis. Unadjusted and adjusted odds ratios (ORs) and their 95% confidence intervals (CIs) controlling for age, gender, education, marital status, caloric intake and BMI were estimated. Test for trend with increasing number of daily amount of cigarettes smoked was also conducted, and a two-sided p-value < 0.05 was considered significant. The Statistical Package for the Social Sciences 22.0.1 (SPSS Inc., Chicago, IL, USA) was used for all computations.

Results

The socio-demographic and health-related characteristics of the study sample are summarized in Table 1. The sample was equally divided by gender (49.9% females and 50.1% males), with a mean age of 39.2 ± 15.2 years (range 18 to 92 years). The majority were married (60.6%), and close to half of the participants were employed (52.3%) at the time of the study, with a high percentage having less than complementary education (39.7%). Ever smokers constituted 37.5% of the sample, 41.6% were classified as being engaged in low-intensity physical activity, and 39.7% reported ever alcohol drinkers. Average daily energy intake was estimated at 2656 ± 1249 Kcal/day, with 36.5% of caloric intake from fat, 11.4%% from saturated fat, 49.1% from carbohydrates, 5.7% from sugar, and 15.2% from protein. Abnormal levels of TC, TG, VLDL, LDL-C, and HDL-C were observed for 55.4%, 31.4%, 29.2%, 47.5% and 21.8% of the participants, respectively.

Insert table 1 around here

Tables 2a and 2b show the unadjusted and adjusted ORs for the association between behavioral risk factors and dietary variables with blood lipids levels. Associations with cigarette smoking were positive for most outcomes but significant for those consuming more than 40 cigarettes/day, compared to non-smokers, in the case of TG (unadjusted OR = 5.03) and VLDL (OR = 4.09) and HDL-C OR = 3.02). Adjusting for potential confounders, the associations maintained statistical significance for TG and VLDL, with an adjusted OR of 4.27 (95% CI 1.69- 10.77) and 3.26 (95% CI 1.33-8.03), respectively. Results showed a dose-response relationship with increasing number of cigarettes consumed for (p-value for trend = 0.010 and 0.030, respectively). In addition, a statistically significant association was observed between ever alcohol drinking and LDL-C (OR=1.53). This association retained statistical significance even after adjustment for potential confounders with an OR of 1.68 (95% CI 1.01-2.82). Out of all the dietary variables examined, only saturated fat was associated with blood lipids, namely TC and LDL-C, with an adjusted OR of 1.73 for both lipid abnormalities (95% CI 1.02-2.94 and 1.02-2.93, respectively). Physical activity was not associated with any of the blood lipid parameters.

Insert tables 2a and 2b around here

Discussion

Our results showed that heavy cigarette smoking is associated with increased levels of TG and VLDL, with findings showing significant dose-response relationships with increasing number of cigarettes smoked per day. The study also showed that alcohol drinking and high saturated fat intake are significantly associated with higher levels of LDL-C. However, there were no consistent associations between physical activity and fasting blood lipids profile. To

our knowledge, this is the first study in Lebanon to explore these associations, based on objectively measured lipid parameters and using standardized laboratory techniques and tools, while taking into consideration the effect of potential confounders.

There are strong indicators in the literature that the deleterious effect of cigarette smoking on heart disease and atherosclerosis is partially explained by the effect of smoking on the concentration of blood lipids and lipoproteins. Our study confirms the results of earlier cross-sectional studies showing that the association between smoking and lipoproteins are observed in the levels of TG, VLDL and HDL-C, [6, 28, 29] with the impact on lipid levels increasing with increase in the number of cigarettes smoked/day in a dose dependent relationship. [30, 31] Our observation of the largest effect of cigarette smoking on lipid parameters being seen in those who smoked more than two packs a day is also consistent with Chen et al. study comprising of 1,164 men in Taiwan. [32] One popular mechanism by which smoking affects lipoproteins is that cigarette particulate matter alters catecholamine release—and thus free fatty acid release, which in turn contributes to the accumulation of the LDL-C concentrations and to lower levels of HDL-C in the blood. [33] The association between cigarette smoking and the increase in TG can also be explained by the decrease in the activity of the lipoprotein lipase among smokers thus disrupting lipid and lipoprotein metabolism. Furthermore, smoking cessation was found to improve lipid and lipoprotein levels in observational studies and randomized clinical trials. [7, 34] Taken together, the totality of evidence from these studies and our data-including consistency upon replication across various studies, the dose-response relationship, the magnitude and significance of association, biological plausibility as well as effects of smoking cessation on lipoprotein levels, supports a strong relationship between smoking and lipid profiles.

Our study showed that alcohol drinking was associated with higher LDL-C levels in Lebanese adults, but was not associated with other lipid parameters. Available evidence on the impact of alcohol on LDL-C is conflicting with recent studies suggesting that the association of alcohol and LDL-C levels may be population-specific. [35] For instance, studies conducted amongst Danish adults reported an inverse association between alcohol intake and LDL-C, [36] while studies conducted in Spanish and Italian populations found that higher alcohol consumption was associated with increased LDL-C. [37, 38] According to a review by Brinton (2012), these inconsistent findings on the association between alcohol intake and LDL-C, may be explained by allele-specific genetic effects, such as the Apo E4 and Apo A5 genes.[, 39] In our study, alcohol drinking was not associated with HDL-C levels. Findings on the relationship between alcohol and HDL-C have in fact been less consistent in the literature, with some but not all showing an effect on higher HDL-C levels. [40, 41] Indeed, the effect of alcohol on CVD including coronary artery disease, stroke and myocardial infarction appears to be biphasic showing a J or U-shaped relationship based on the amount of alcohol consumed, [41, 42] with lower CVD mortality risks by light to moderate alcohol consumption and increased risk by heavy alcohol intake.[43] The discrepancy between our results with those in the literature may be due to differences in race/ethnicity and genetic variations, [44] or alternatively, owing to measurement error in our assessment of alcohol consumption, based on self-reports of a dichotomous variable. Lipid profiles are influenced by the type of alcohol consumed and by drinking frequency and patterns.

Dietary intakes are amongst the modifiable risk factors that may modulate plasma lipids and the risk of CVD. In our study, saturated fat was the only dietary factor that was significantly associated with lipid parameters, and specifically with TC and LDL-C. Despite the increasing controversy around the relationship between saturated fat and blood cholesterol levels, an increasing body of evidence highlights the strong atherogenicity of saturated fatty

acids through their impact on LDL-C. [14] A systematic review and meta-regression analysis published in 2016 showed that a decrease in saturated fats of 1% of daily energy intake coupled with an increase of 1% in polyunsaturated fat, lowered LDL cholesterol by 2.1 mg/dL.[45] In 2017, a Presidential Advisory from the American Heart Association (AHA) concluded that available evidence strengthens the long-standing AHA recommendations to decrease saturated fat intake and replace it with unsaturated fats. The AHA Advisory highlighted that the shift from saturated to unsaturated fats should occur in the context of an overall healthful dietary pattern such as the DASH or Mediterranean patterns. [14]

In our study, physical activity did not appear to be associated with lipid parameters. The literature suggests that physical activity increases the level of HDL-C and has beneficial effects on lipoprotein particle size and number. [46] Also, moderate intensity exercise is known to have a more favorable effect on blood lipids since it allows the use of lipids as a fuel source which implies an increase in the uptake and oxidation of the lipids in the skeletal muscle. [46]

Some other limitations should be taken into consideration when interpreting the results of our study. Because the study used a cross-sectional design, findings only imply associations and causal relationships cannot be established. The proportion of participants who gave fasting blood samples (of at least 8 hours) was relatively small (27.3%); however, responders were comparable to non-responders on a number of socio-demographic characteristics except for marital status (61% of responders vs. 50% of non-responders were married). Also, we had earlier documented comparable dietary data between respondents and non-respondents based on factor loading matrices on patterns of food groups intake. [4] As mentioned earlier, measures of exposure were self-reported which can introduce some misclassification error. Whilst this may have been problematic in the case of alcohol consumption that lacked

detailed data on type of alcohol consumed, measurement of cigarette smoking and physical activity were more detailed and reliable. Information on cigarette smoking in our study included the amount of cigarettes smoked and the standardized IPAQ was used to assess physical activity.

To conclude, our results suggest that smoking, alcohol drinking and high saturated fat are associated with adverse levels of lipoprotein, among Lebanese men and women. The role of lipoproteins in atherogenesis has been clearly defined, and controlling for blood lipid levels decreases the risk of heart and many other chronic diseases. Our findings lay further evidence for clinical practitioners, public health professionals and dieticians regarding the potential benefits of lifestyle and dietary modifications in their pursuit to curb the burden of hyperlipidemia and CVD at the individual and population level. The overall high rate of smoking behavior in Lebanon among both men and women, coupled with the shift in dietary patterns towards high fat energy dense foods, [4, 15] are likely to adversely impact on the healthcare bill in the country. Further studies with larger sample size that examine the association of combination patterns of poor lifestyle factors on lipid profile among Lebanese adults are warranted.

Contributors
MM conducted initial analyses and wrote first draft of the paper, in partial fulfillment of her MSc in Epidemiology. HT supervised the conduct of analyses and contributed to the write-up of the paper. LN conducted the dietary analyses and contributed to the write-up of the paper. CK, NH, MC and AF provided statistical advice and contributed to the paper revision. AMS coordinated original study conduct, conceived and finalized the analyses, and wrote the manuscript. All authors read and approved the final version of the manuscript.

Funding statement
The original study conduct was funded by the World Health Organization (WHO) - Lebanon. However, no funds were available for this secondary analysis.

Data sharing statement
The dataset was available for all authors of the study and will be available for other non-commercial researchers upon request.

Declaration of conflicting interests
The authors declare that there is no conflict of interest.

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Table 1 Distribution of socio-demographic characteristics, behavioral factors and lipid profile of the study population.

	n	%
Gender (% female)	181	49.9
Age (mean ± SD, years)	39.2 ± 15.2	
18-29	113	31.1
30-39	106	29.2
40-49	67	18.5
50-59	32	8.8
≥60	45	12.4
Marital Status		
Single	128	35.3
Married	220	60.6
Divorced/widowed	15	4.1
Work Status		
Student or volunteer	31	8.5
Employed	190	52.3
Does not work/housewife/retired	142	39.1
Educational Level		
Complementary or less	144	39.7
Secondary or technical	99	27.3
University and above	120	33.1
Cigarette Smoking		
Never smoked	227	62.5
Past smoker	15	4.2
Current smoker	121	33.3
Number of cigarettes smoked/day		
0	227	62.5
1-19	43	11.8
20-39	63	17.4
≥40	30	8.3
Physical activity		
Low-intensity activity	151	41.6
Moderate-intensity activity	121	33.3
High-intensity activity	88	24.2
Alcohol consumption (ever drinker)	144	39.7
Total caloric intake (mean ± SD, Kcal/day)	2656 ± 1249	
Fat intake (% of total energy) [a]	36.5 ± 6.89	
≥ 30 [b]	275	81.6
Saturated fat intake (% of total energy) [a]	11.4 ± 2.92	
≥10 [c]	224	66.5
Carbohydrates intake (% of total energy) [a]	49.1 ± 7.03	
≥55 [b]	71	21.1
Sugar (% of total energy) [a]	5.7 ± 4.64	
≥ 10 [d]	56	16.6
Proteins intake (% of total energy) [a]	152 ± 2.91	
<15 [b]	143	42.4
Total Cholesterol (mean ± SD, mg/dl)	210 ± 45	
% Elevated total cholesterol (≥200 mg/dl) [e]	201	55.4
Triglycerides (mean ± SD, mg/dl)	138 ± 78	
% Elevated triglycerides (≥150 mg/dl) [e]	114	31.4

VLDL (mean ± SD, mg/dl)	27 ± 15	
% Elevated VLDL (≥30 mg/dl) [e]	106	29.2
LDL-C (mean ± SD, mg/dl)	131 ± 39	
% Elevated LDL-C (≥130 mg/dl) [e]	172	47.5
HDL-C (mean ± SD, mg/dl)	51 ± 14	
% Reduced HDL-C (≤40 mg/dl) [e]	79	21.8

[a] Dietary variables are based on a sample of 337 subjects owing to missing data
[b] Macronutrient cutoffs are within the Acceptable Macronutrient Distribution Range (AMDR) [25]
[c] Saturated fat cutoff based on the WHO recommendations [26]
[d] Sugar intake cutoff based on the WHO recommendations [27]
[e] Lipid cutoff values based on the Adult Treatment Panel III guidelines [21] ;Very Low Density Lipoprotein (VLDL); Low Density Lipoprotein cholesterol (LDL-C); High Density Lipoprotein cholesterol (HDL-C)

Table 2a Logistic regression analysis: associations of behavioral risks with total cholesterol (TC) and triglycerides (TG)

		TC			TG		
		% ≥200 mg/dl	Crude OR (CI)	Adjusted* OR (CI)	% ≥150 mg/dl	Crude OR (CI)	Adjusted* OR (CI)
Number of Cigarettes	0	52.0	1.00	1.00	25.6	1.00	1.00
	1-19	55.8	1.17 (0.60-2.25)	0.85 (0.40-1.77)	30.2	1.26 (0.62-2.58)	1.06 (0.48-2.33)
	20-35	63.5	1.60 (0.90-2.85)	1.01 (0.51-2.00)	38.1	1.79 (0.99-3.23)	1.30 (0.67-2.53)
	≥40	63.3	1.59 (0.73-3.50)	1.24 (0.48-3.18)	63.3	5.03 (2.26-11.2)	4.27 (1.69-10.77)
	p-trend		0.070	00.783		<0.001	0.010
Physical activity	High	55.7	1.00	1	25.0	1.00	1
	Moderate	56.2	1.02 (0.59-1.77)	0.89 (0.48-1.67)	32.2	1.43 (0.77-2.64)	1.64 (0.83-3.25)
	Low	55.6	0.99 (0.59-1.69)	1.11 (0.31-2.00)	35.1	1.62 (0.90-2.92)	1.75 (0.93-3.29)
Alcohol intake	No	53	1	1	31.5	1	1
	Yes	59	1.28 (0.84-1.96)	1.52 (0.90-2.55)	31.3	0.99 (0.63-1.56)	0.98 (0.57-1.69)
Total fat intake (% energy)	<30	54.8	1	1.00	30.6	1	1
	≥30	54.9	1.03 (0.57-1.74)	1.15 (0.62-2.13)	31.3	1.03 (0.57-1.87)	1.22 (0.34-2.35)
Saturated Fat (% energy)	<10	52.2	1	1	31	1	1
	≥10	56.3	1.17 (0.75-1.85)	1.73 (1.02-2.94)	31.3	1.01 (0.62-1.65)	1.01 (0.59-1.74)
Carbohydrates (% energy)	<55	53.8	1	1	30.8	1	1
	≥55	59.2	1.25 (0.73-2.12)	1.07 (0.59-1.93)	32.4	1.07 (0.61-1.88)	0.96 (0.52-1.76)
Sugar intake (% energy)	<10	54.8	1	1	32	1	1
	≥10	55.4	1.02 (0.57-1.82)	1.12 (0.59-2.16)	26.8	0.78 (0.41-1.48)	0.86 (0.43-1.73)
Protein intake (% energy)	<15	56.6	1	1	36.4	1	1
	≥15	53.6	0.88 (0.57-1.37)	0.83 (0.50-1.37)	27.3	0.66 (0.41-1.05)	0.79 (0.47-1.32)

*Controlling for age, gender, education, marital status, caloric intake and BMI

Table 2b Logistic regression analysis: associations of behavioral risks with very low-density lipoprotein (VLDL), low-density lipoprotein cholesterol (LDL-C) and high-density lipoprotein cholesterol (HDL-C).

		VLDL			LDL-C			HDL-C		
		%≥30 mg/dl	Crude OR (CI)	Adjusted* OR (CI)	%≥130 mg/dl	Crude OR (CI)	Adjusted* OR (CI)	%<40 mg/dl	Crude OR (CI)	Adjusted* OR (CI)
Number of Cigarettes	0	24.2	1.00	1	43.6	1.00	1	18.1	1.00	1.00
	1-19	27.9	1.21 (0.58-2.52)	1.01 (0.45-2.25)	53.5	1.49 (0.77-2.86)	1.12 (0.54-2.33)	18.6	1.04 (0.45-2.40)	1.01 (0.39-2.63)
	20-39	35.5	1.72 (0.94-3.14)	1.27 (0.64-2.51)	54.8	1.57 (0.89-2.76)	0.97 (0.50-1.89)	28.6	1.81 (0.95-3.45)	1.61 (0.75-3.45)
	≥40	56.7	4.09 (1.87-8.95)	3.26 (1.33-8.03)	53.3	1.48 (0.69-3.17)	0.96 (0.39-2.40)	40.0	3.02 (1.35-6.76)	1.98 (0.77-5.08)
	p-trend		<0.001	0.030		0.078	0.946		<0.001	0.106
Physical activity	High	26.1	1.00	1	48.9	1.00	1	27.3	1.00	1
	Moderate	28.9	1.15 (0.62-2.13)	1.27 (0.54-2.52)	49.6	1.02 (0.59-1.78)	0.89 (0.48-1.65)	19.0	0.62 (0.32-1.20)	0.93 (0.43-2.01)
	Low	32.0	1.33 (0.74-2.39)	1.44 (0.76-2.71)	46.0	0.89 (0.53-1.51)	0.93 (0.52-1.65)	21.2	0.72 (0.40-1.32)	0.69 (0.34-1.39)
Alcohol intake	No	28.3	1	1	43.4	1	1	20.5	1	1
	Yes	30.8	1.12 (0.71-1.79)	1.12 (0.65-1.93)	53.8	1.53 (1.00-2.33)	1.68 (1.01-2.82)	23.6	1.19 (0.72-1.98)	0.98 (0.54-1.78)
Total fat intake (% energy)	<30	29.0	1	1	45.2	1	1	25.8	1	1
	≥ 30	28.8	0.99 (0.54-1.82)	1.15 (0.59-2.22)	46.7	1.06 (0.61-1.85)	1.26 (0.69-2.33)	21.8	0.80 (0.42-1.52)	0.81 (0.39-1.65)
Saturated Fat (% energy)	<10	29.2	1	1	44.2	1	1	20.4	1	1
	≥ 10§	28.7	0.98 (0.59-1.61)	0.96 (0.56-1.66)	47.5	1.15 (0.72-1.80)	1.73 (1.02-2.93)	23.7	1.21 (0.70-2.16)	1.16 (0.62-2.17)
Carbohydrates (% energy)	<55	28.7	1	1	45.7	1	1	22.2	1	1
	≥55	29.6	1.04 (0.59-1.86)	0.96 (0.52-1.79)	49.3	1.16 (0.68-1.95)	0.93 (0.52-1.67)	23.9	1.10 (0.60-2.05)	1.18 (0.59-2.36)
Sugar intake (% energy)	<10	29.6	1	1	47.1	1	1	23.8	1	
	≥10	25.0	0.79 (0.41-1.53)	0.89 (0.44-1.82)	42.9	0.84 (0.47-1.50)	0.89 (0.47-1.71)	16.1	0.61 (0.28-1.31)	0.62 (0.26-1.45)
Protein intake (% energy)	<15	32.9	1	1	48.3	1	1	21	1	1
	≥15	25.9	0.71(0.44-1.15)	0.85 (0.50-1.44)	45.1	0.88 (0.57-1.36)	0.75 (0.46-1.24)	23.7	1.17 (0.59-1.97)	1.49 (0.82-2.72)

*Controlling for age, gender, education, marital status, caloric intake and BMI

BMJ Open

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Journal:	*BMJ Open*
Manuscript ID	bmjopen-2018-026148.R2
Article Type:	Research
Date Submitted by the Author:	13-May-2019
Complete List of Authors:	Mansour, Megali; American University of Beirut Faculty of Health Sciences, EPHD Tamim, Hani; American University of Beirut, Biostatistics Unit, Clinical Research Institute Nasreddine, Lara; American University of Beirut EL Khoury, Christelle; Tufts University School of Medicine Hwalla, Nahla; American University of Beirut Chaaya, Monique; American University of Beirut Farhat, Antoine ; Notre Dame University Sibai, Abla; American University of Beirut, EPHD
Primary Subject Heading:	Public health
Secondary Subject Heading:	Epidemiology, Nutrition and metabolism, Smoking and tobacco, Public health
Keywords:	PUBLIC HEALTH, EPIDEMIOLOGY, Cigarette Smoking, Blood lipids

Prevalence and associations of behavioral risk factors with blood lipids profile in Lebanese adults: findings from the WHO STEPwise NCD Survey

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Keywords: Cardiovascular disease, smoking, alcohol consumption, physical inactivity, dietary intake, blood lipids, Lebanon

Word count (excluding title page, references, tables and figures): 3141

Abstract

Objective: To examine associations of behavioral risk factors, namely cigarette smoking, physical activity, dietary intakes and alcohol consumption, with blood lipids profile.

Design and participants: Data drawn from a cross-sectional study involving participants aged 18 years and over (n = 363) from the nationwide WHO Stepwise Nutrition and Non-communicable Disease Risk Factor survey in Lebanon.

Measures: Demographic characteristics, behaviors and medical history were obtained from participants by questionnaire. Dietary assessment was performed using a 61-item culture-specific food frequency questionnaire that measured food intake over the past year. Lipid levels were measured by analysis of fasting blood samples (serum total cholesterol (TC), triglycerides (TG), very low-density lipoprotein (VLDL), low-density lipoprotein cholesterol (LDL-C) and high-density lipoprotein cholesterol (HDL-C).

Results: Current cigarette smoking, alcohol consumption and low physical activity were prevalent among 33.3%, 39.7%, and 41.6% of the sample, respectively. The contributions of fat and saturated fat to daily energy intake were high, estimated at 36.5% and 11.4%, respectively. Abnormal levels of TC, TG, VLDL, LDL-C, and HDL-C were observed for 55.4%, 31.4%, 29.2%, 47.5% and 21.8% of participants, respectively. Adjusting for potential confounders, cigarette smoking was positively associated with higher odds of TG and VLDL (OR=4.27; 95% CI 1.69-10.77; and 3.26; 95% CI 1.33-8.03, respectively) with a significant dose-response relationship (p-value for trend=0.010 and 0.030, respectively). Alcohol drinking and high saturated fat intake (≥10% energy intake) were associated with higher odds of LDL-C (OR=1.68; 95% CI: 1.01-2.82 and OR= 1.73; 95% CI: 1.02-2.93). Physical activity did not associate significantly with any blood lipid parameter.

Conclusion: The demonstrated positive associations between smoking, alcohol drinking and high saturated fat intake with adverse lipoprotein levels lay further evidence for clinical

practitioners, public health professionals and dietitians in the development of preventive strategies among subjects with high risk of CVDs in Lebanon.

Strengths and limitations

- A nationwide survey administered in Lebanon, following the WHO STEPwise approach to surveillance guidelines, thus allowing for comparison with international literature.
- Low response rate (27.3%) for those who consented and gave fasting blood samples. Yet, differences between responders and non-responders were not significant on a number of socio-demographic characteristics.
- Whilst data on smoking, physical activity and dietary intakes were sufficiently detailed, measures of exposure to alcohol consumption lacked information on intensity and type, and may be prone to misclassification bias.
- Attention to associations between behavioral factors and dietary intakes with intermediary metabolic conditions along the causal pathway for CVD informs work towards development of tailored preventive strategies for high risk individuals.

Introduction

The prevalence of cardiovascular diseases (CVD) is growing worldwide, and has reached epidemic levels, affecting both developed and developing countries.[1] The Middle East and North Africa countries represent a region which is now facing a fast rate of development and urbanization, with rates of chronic diseases increasing at an alarming rate and exceeding at times those of developed countries.[2] In Lebanon, a small middle-income country at the Eastern Mediterranean shore, data from the World Health Organization (WHO) indicate that the proportional mortality from CVD alone is 45%, making it the highest among all non-communicable diseases (NCDs).[3] With a population estimate of around 4.2 million and a Gross Domestic Product (GDP) of close to 8,520 US Dollars per capita, Lebanon is characterized by a high urbanization rate (87%), a growing trend towards survival in later life, coupled with westernization and modernization in diet and lifestyle and higher uptake of NCD risk factors.[4]

The primary goal in the prevention and management of CVD is to identify and modify the underlying risk behaviors that are amenable to intervention, namely, cigarette smoking, physical inactivity, dietary intakes and alcohol consumption. Associations between these factors and CVD risk through their effect on blood lipid levels have been widely examined in the western literature. Studies have shown that smokers are 2-4 times more at risk of developing heart disease than nonsmokers[5] and the number of cigarettes smoked/day independently predicts higher levels of Total Cholesterol (TC), Low Density Lipoprotein-Cholesterol (LDL-C), and Triglycerides (TG).[6] Also, smoking cessation has been shown to improve High Density Lipoprotein-Cholesterol (HDL-C) levels.[7] Cigarette smoking is described as a strong inflammation mediator and a key promoter in the atherosclerotic process. Similarly, the anti-inflammatory effect of frequent physical activity has been noted to be the reason behind reduced heart disease risk among physically active individuals.[8]

Regular physical activity with weight reduction has a large beneficial impact on the lipoproteins profile of adult men and women, [9] by increasing plasma volume, decreasing blood thickness, and thus reducing LDL-C concentrations. [10] Also, systematic reviews and meta-analysis of intervention studies have shown that heavy alcohol drinking results in an elevation in triglyceride levels, while moderate consumption increases circulating levels of HDL-C. [11] Similarly, diet is recognized as a modifiable risk factor that can make a substantial contribution to the risk of CVD. [12 13] Energy intake, the types of fatty acids consumed and the level of sugar ingestion may impact the lipid and cardiometabolic profile.[14] The 2017 Presidential Advisory from the American Heart Association indicated that replacement of saturated fat with unsaturated fatty acids decreases LDL-C levels and CVD risk, while replacing it with refined carbohydrates and sugar, yields no significant benefits to cardiovascular health. [14]

Much of the above evidence comes from studies conducted in North American and European countries and to a lesser extent from the Far East, mostly among Japanese and Korean population. Arab populations including the Lebanese have quite different risk behaviors, varied dietary habits and risk profile, [15] and studies evaluating the association between behaviors and intermediary variables along the causal pathway of CVD including lipid levels remain scarce in the region. Compared with other neighboring countries, Lebanon was shown to have one of the highest prevalence estimates of metabolic syndrome, [16] and has been witnessing high rates of smoking, among both adult men and women aged 18 years and over (42.9% and 27.5%, respectively).[17] Using data from a nationwide population-based survey of Lebanese adults, this study aims to examine the relation between behavioral risk factors including cigarette smoking, physical activity, dietary intakes and alcohol consumption with serum lipids and lipoproteins, while taking into account several potential confounding factors. Findings

from this study inform prevention strategies among subjects with high risk of CVD in the country.

Methods

Study design and participants

The data presented in this study are derived from the WHO Nutrition and Non-Communicable Diseases Risk Factor (NNCD-RF) cross-sectional household survey conducted in Lebanon in 2009. [18] Using multi-stage stratified cluster study design, the sampling was based on the age-sex distribution of the Lebanese population as provided by the Central Administration for Statistics. One adult was randomly selected from each household using Kish methodology. [19] Pregnant and lactating women and individuals with mental disabilities were excluded. With a non-response rate of 10% at the individual level, this yielded a sample of 2668 survey participants aged 18 years and above. Those free from known history of hyperlipidemia and diabetes in the first phase of the study (n = 1,331) were approached to undergo a biochemical assessment, of which 363 provided written consent and gave fasting blood samples. Further details on the design and sample of the survey are published elsewhere. [4] The study protocol was approved by the Institutional Review Board of the American University of Beirut (AUB), and informed consent was taken from all participants.

Data collection

The data collection procedure followed the WHO STEPwise approach to Surveillance, [20] and included the following three steps: Step 1 Questionnaire, whereby information about socio-demographic characteristics, NCDs and NCD risk factors, including dietary intake, were collected through face-to-face interviews; Step 2 in which anthropometric and blood pressure

measurements were taken using standardized techniques and calibrated equipment; and finally, Step 3 in which biochemical analysis for assessment of the blood lipid profile was performed on blood samples collected after an overnight fast of at least 8 hours. Serum was centrifuged on site and shipped on dry ice to the AUB Laboratory.

Measures of blood lipids

Levels of blood lipids including TC, TG, very low density lipoprotein (VLDL), LDL-C and HDL-C were analyzed using the Vitros 350 analyzer, an enzymatic spectrophotometric technique. The inter-assay variation of measurements did not exceed 4%. Quality control was performed within each run using standard performance verifier solutions provided by Ortho-Clinical Diagnostics. Analyses were conducted in duplicates, and the average value was utilized in the analysis. Based on the Adult Treatment Panel III guidelines, [21] the cutoff points used for the definition of risk levels of TC, TG, VLDL, LDL-C and HDL-C were ≥200, ≥150, ≥30, ≥130 and ≤40 mg/dl, respectively.

Behavioral risk factors and other measures

Behavioral risk factors examined in this study included cigarette smoking, physical activity, and alcohol consumption. Cigarette smoking status (never, past and current) and intensity (number of cigarettes smoked/day) were assessed. Intensity was later categorized into three levels according to number of cigarettes/day (1 to 19, 20 to 39 and ≥40). The short version of the International Physical Activity Questionnaire was used to assess physical activity among participants. [22] Three categories of physical activity (low, moderate, and high) were assigned based on METs-min/week (MET-min being the product of the resting metabolic rate for an activity and the number of minutes taken to perform it). Alcohol-related behavior was assessed as a dichotomous variable (ever vs never). Dietary assessment was performed using

a 61-item culture-specific food frequency questionnaire that measured food intake over the past year. [4, 15] Intakes of energy and macronutrients were estimated using the food composition database of the Nutritionist IV software, and the food composition table for local and traditional Middle-Eastern foods. [23,24] Intakes of carbohydrates, fat and protein were compared to cut-offs within the Acceptable Macronutrient Distribution Range, [25] and intakes of saturated fat and sugar were compared to the recommendations of the WHO. [26, 27]

Covariates of interest included total daily caloric intake and body mass index (BMI), measured as the ratio of weight (kilograms) to the square of height (meters). In addition, gender, age (18-29, 30-39, 40-49, 50-59, and ≥60), marital status (single, married, divorced/widowed), education level (complementary or less, secondary/technical, university and above), and occupational status (student/volunteer, working, does not work/housewife/retired) were considered as potential covariates.

Patient and Public Involvement

This study is based on secondary data analyses. The original data collection tool was adapted from the WHO STEPwise approach to NCD risk factor surveillance, [20] that did not directly involve patients or the public in outcome development or conduct of the study. However, we have been engaging with stakeholders to disseminate the findings on NCD risk factors, including tobacco consumption and dietary intakes, and on associations with various health-related outcomes to the public at large.

Statistical analysis

Means, standard deviations (SD) and frequencies were used to describe the various socio-demographic, behavioral, nutritional and clinical characteristics of the participants. The

associations between each of the risk factors and levels of the different blood lipids were examined using multiple logistic regression analysis. Unadjusted and adjusted odds ratios (ORs) and their 95% confidence intervals (CIs) controlling for age, gender, education, marital status, caloric intake and BMI were estimated. Test for trend with increasing number of daily amount of cigarettes smoked was also conducted, and a two-sided p-value < 0.05 was considered significant. The Statistical Package for the Social Sciences 22.0.1 (SPSS Inc., Chicago, IL, USA) was used for all computations.

Results

The socio-demographic and health-related characteristics of the study sample are summarized in Table 1. The sample was equally divided by gender (49.9% females and 50.1% males), with a mean age of 39.2 ± 15.2 years (range 18 to 92 years). The majority were married (60.6%), and close to half of the participants were employed (52.3%) at the time of the study, with a high percentage having less than complementary education (39.7%). Ever smokers constituted 37.5% of the sample, 41.6% were classified as being engaged in low-intensity physical activity, and 39.7% reported ever alcohol drinkers. Average daily energy intake was estimated at 2656 ± 1249 Kcal/day, with 36.5% of caloric intake from fat, 11.4%% from saturated fat, 49.1% from carbohydrates, 5.7% from sugar, and 15.2% from protein. Abnormal levels of TC, TG, VLDL, LDL-C, and HDL-C were observed for 55.4%, 31.4%, 29.2%, 47.5% and 21.8% of the participants, respectively.

Insert table 1 around here

Tables 2a and 2b show the unadjusted and adjusted ORs for the association between behavioral risk factors and dietary variables with blood lipids levels. Associations with cigarette smoking were positive for most outcomes but significant for those consuming more than 40 cigarettes/day, compared to non-smokers, in the case of TG (unadjusted OR = 5.03) and VLDL (OR = 4.09) and HDL-C OR = 3.02). Adjusting for potential confounders, the associations maintained statistical significance for TG and VLDL, with an adjusted OR of 4.27 (95% CI 1.69- 10.77) and 3.26 (95% CI 1.33-8.03), respectively. Results showed a dose-response relationship with increasing number of cigarettes consumed for (p-value for trend = 0.010 and 0.030, respectively). In addition, a statistically significant association was observed between ever alcohol drinking and LDL-C (OR=1.53). This association retained statistical significance even after adjustment for potential confounders with an OR of 1.68 (95% CI 1.01-2.82). Out of all the dietary variables examined, only saturated fat was associated with blood lipids, namely TC and LDL-C, with an adjusted OR of 1.73 for both lipid abnormalities (95% CI 1.02-2.94 and 1.02-2.93, respectively). Physical activity was not associated with any of the blood lipid parameters.

Insert tables 2a and 2b around here

Discussion

Our results showed that heavy cigarette smoking is associated with increased levels of TG and VLDL, with findings showing significant dose-response relationships with increasing number of cigarettes smoked per day. The study also showed that alcohol drinking and high saturated fat intake are significantly associated with higher levels of LDL-C. However, there were no consistent associations between physical activity and fasting blood lipids profile. To

our knowledge, this is the first study in Lebanon to explore these associations, based on objectively measured lipid parameters and using standardized laboratory techniques and tools, while taking into consideration the effect of potential confounders.

There are strong indicators in the literature that the deleterious effect of cigarette smoking on heart disease and atherosclerosis is partially explained by the effect of smoking on the concentration of blood lipids and lipoproteins. Our study confirms the results of earlier cross-sectional studies showing that the association between smoking and lipoproteins are observed in the levels of TG, VLDL and HDL-C, [6, 28, 29] with the impact on lipid levels increasing with increase in the number of cigarettes smoked/day in a dose dependent relationship. [30, 31] Our observation of the largest effect of cigarette smoking on lipid parameters being seen in those who smoked more than two packs a day is also consistent with Chen et al. study comprising of 1,164 men in Taiwan. [32] One popular mechanism by which smoking affects lipoproteins is that cigarette particulate matter alters catecholamine release—and thus free fatty acid release, which in turn contributes to the accumulation of the LDL-C concentrations and to lower levels of HDL-C in the blood. [33] The association between cigarette smoking and the increase in TG can also be explained by the decrease in the activity of the lipoprotein lipase among smokers thus disrupting lipid and lipoprotein metabolism. Furthermore, smoking cessation was found to improve lipid and lipoprotein levels in observational studies and randomized clinical trials. [7, 34] Taken together, the totality of evidence from these studies and our data-including consistency upon replication across various studies, the dose-response relationship, the magnitude and significance of association, biological plausibility as well as effects of smoking cessation on lipoprotein levels, supports a strong relationship between smoking and lipid profiles.

Our study showed that alcohol drinking was associated with higher LDL-C levels in Lebanese adults but was not associated with other lipid parameters. Available evidence on the impact of alcohol on LDL-C is conflicting with recent studies suggesting that the association of alcohol and LDL-C levels may be population-specific. [35] For instance, studies conducted amongst Danish adults reported an inverse association between alcohol intake and LDL-C, [36] while studies conducted in Spanish and Italian populations found that higher alcohol consumption was associated with increased LDL-C. [37, 38] According to a review by Brinton (2012), these inconsistent findings on the association between alcohol intake and LDL-C, may be explained by allele-specific genetic effects, such as the Apo E4 and Apo A5 genes.[, 39] In our study, alcohol drinking was not associated with HDL-C levels. Findings on the relationship between alcohol and HDL-C have in fact been less consistent in the literature, with some but not all showing an effect on higher HDL-C levels. [40, 41] Indeed, the effect of alcohol on CVD including coronary artery disease, stroke and myocardial infarction appears to be biphasic showing a J or U-shaped relationship based on the amount of alcohol consumed, [41, 42] with lower CVD mortality risks by light to moderate alcohol consumption and increased risk by heavy alcohol intake.[43] The discrepancy between our results with those in the literature may be due to differences in race/ethnicity and genetic variations, [44] Alternatively, this discrepancy may be due to the definition of alcohol exposure adopted in our study which was based on a dichotomous variable (ever vs never), and thus does not capture alcohol intake in terms of frequency, intensity, types and pattern of alcohol consumed. It is important to also acknowledge that alcohol consumption may be subject to reporting bias in the Lebanese society due to cultural or religious norms. The observed association between alcohol and lipid profile should therefore be interpreted with caution, as it may have been the artifact of other social or lifestyle factors that were not measured in our study.

Dietary intakes are amongst the modifiable risk factors that may modulate plasma lipids and the risk of CVD. In our study, saturated fat was the only dietary factor that was significantly associated with lipid parameters, and specifically with TC and LDL-C. Despite the increasing controversy around the relationship between saturated fat and blood cholesterol levels, an increasing body of evidence highlights the strong atherogenicity of saturated fatty acids through their impact on LDL-C. [14] A systematic review and meta-regression analysis published in 2016 showed that a decrease in saturated fats of 1% of daily energy intake coupled with an increase of 1% in polyunsaturated fat, lowered LDL cholesterol by 2.1 mg/dL.[45] In 2017, a Presidential Advisory from the American Heart Association (AHA) concluded that available evidence strengthens the long-standing AHA recommendations to decrease saturated fat intake and replace it with unsaturated fats. The AHA Advisory highlighted that the shift from saturated to unsaturated fats should occur in the context of an overall healthful dietary pattern such as the DASH or Mediterranean patterns. [14]

In our study, physical activity did not appear to be associated with lipid parameters. The literature suggests that physical activity increases the level of HDL-C and has beneficial effects on lipoprotein particle size and number. [46] Also, moderate intensity exercise is known to have a more favorable effect on blood lipids since it allows the use of lipids as a fuel source which implies an increase in the uptake and oxidation of the lipids in the skeletal muscle. [46]

Some other limitations should be taken into consideration when interpreting the results of our study. Because the study used a cross-sectional design, findings only imply associations and causal relationships cannot be established. The proportion of participants who gave fasting blood samples (of at least 8 hours) was relatively small (27.3%); however, responders were comparable to non-responders on a number of socio-demographic characteristics except for

marital status (61% of responders vs. 50% of non-responders were married). Also, we had earlier documented comparable dietary data between respondents and non-respondents based on factor loading matrices on patterns of food groups intake. [4] As mentioned earlier, measures of exposure were self-reported which can introduce some misclassification error. This may have been particularly problematic in the case of alcohol consumption, given that our definition based on a dichotomous variable of "ever" vs "never" does not allow for the assessment of drinking frequency and patterns or the type of alcohol consumed. In contrast, our measurement of cigarette smoking and physical activity were more detailed and reliable. Information on cigarette smoking in our study included the amount of cigarettes smoked and the standardized IPAQ was used to assess physical activity.

To conclude, our results suggest that smoking, alcohol drinking and high saturated fat are associated with adverse levels of lipoprotein, among Lebanese men and women. There is enough evidence in the literature indicating the role of lipoproteins in atherogenesis and that controlling for blood lipid levels decreases the risk of heart and many other chronic diseases. Our findings lay further evidence for clinical practitioners, public health professionals and dieticians regarding the potential benefits of lifestyle and dietary modifications in their pursuit to curb the burden of hyperlipidemia and CVD at the individual and population level. The overall high rate of smoking behavior in Lebanon among both men and women, coupled with the shift in dietary patterns towards high fat energy dense foods, [7, 15] are likely to adversely impact on the healthcare bill in the country. Further studies with larger sample size that examine the association of combination patterns of poor lifestyle factors on lipid profile among Lebanese adults are warranted.

Contributors
MM conducted initial analyses and wrote the first draft, in partial fulfillment of her MSc in Epidemiology. HT supervised the conduct of analyses and contributed to the write-up. LN conducted the dietary analyses and contributed to the write-up and revisions. CK, NH, MC and AF provided statistical advice and contributed to the paper revisions. AMS coordinated original study conduct, conceived and finalized the analyses, and contributed substantially to the write-up and revisions. All authors read and approved the final version of the manuscript.

Funding statement
The original study conduct was funded by the World Health Organization (WHO) - Lebanon. However, no funds were available for this secondary analysis.

Data sharing statement
The dataset was available for all authors of the study and will be available for other non-commercial researchers upon request.

Declaration of conflicting interests
The authors declare that there is no conflict of interest.

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Table 1 Distribution of socio-demographic characteristics, behavioral factors and lipid profile of the study population.

	n	%
Gender (% female)	181	49.9
Age (mean ± SD, years)	39.2 ± 15.2	
18-29	113	31.1
30-39	106	29.2
40-49	67	18.5
50-59	32	8.8
≥60	45	12.4
Marital Status		
Single	128	35.3
Married	220	60.6
Divorced/widowed	15	4.1
Work Status		
Student or volunteer	31	8.5
Employed	190	52.3
Does not work/housewife/retired	142	39.1
Educational Level		
Complementary or less	144	39.7
Secondary or technical	99	27.3
University and above	120	33.1
Cigarette Smoking		
Never smoked	227	62.5
Past smoker	15	4.2
Current smoker	121	33.3
Number of cigarettes smoked/day		
0	227	62.5
1-19	43	11.8
20-39	63	17.4
≥40	30	8.3
Physical activity		
Low-intensity activity	151	41.6
Moderate-intensity activity	121	33.3
High-intensity activity	88	24.2
Alcohol consumption (ever drinker)	144	39.7
Total caloric intake (mean ± SD, Kcal/day)	2656 ± 1249	
Fat intake (% of total energy) [a]	36.5 ± 6.89	
≥ 30 [b]	275	81.6
Saturated fat intake (% of total energy) [a]	11.4 ± 2.92	
≥10 [c]	224	66.5
Carbohydrates intake (% of total energy) [a]	49.1 ± 7.03	
≥55 [b]	71	21.1
Sugar (% of total energy) [a]	5.7 ± 4.64	
≥ 10 [d]	56	16.6
Proteins intake (% of total energy) [a]	152 ± 2.91	
<15 [b]	143	42.4
Total Cholesterol (mean ± SD, mg/dl)	210 ± 45	
% Elevated total cholesterol (≥200 mg/dl) [e]	201	55.4
Triglycerides (mean ± SD, mg/dl)	138 ± 78	
% Elevated triglycerides (≥150 mg/dl) [e]	114	31.4

VLDL (mean ± SD, mg/dl)	27 ± 15	
% Elevated VLDL (≥30 mg/dl) [e]	106	29.2
LDL-C (mean ± SD, mg/dl)	131 ± 39	
% Elevated LDL-C (≥130 mg/dl) [e]	172	47.5
HDL-C (mean ± SD, mg/dl)	51 ± 14	
% Reduced HDL-C (≤40 mg/dl) [e]	79	21.8

[a] Dietary variables are based on a sample of 337 subjects owing to missing data
[b] Macronutrient cutoffs are within the Acceptable Macronutrient Distribution Range (AMDR) [25]
[c] Saturated fat cutoff based on the WHO recommendations [26]
[d] Sugar intake cutoff based on the WHO recommendations [27]
[e] Lipid cutoff values based on the Adult Treatment Panel III guidelines [21] ;Very Low Density Lipoprotein (VLDL); Low Density Lipoprotein cholesterol (LDL-C); High Density Lipoprotein cholesterol (HDL-C)

Table 2a Logistic regression analysis: associations of behavioral risks with total cholesterol (TC) and triglycerides (TG)

		TC			TG		
		% ≥200 mg/dl	Crude OR (CI)	Adjusted* OR (CI)	% ≥150 mg/dl	Crude OR (CI)	Adjusted* OR (CI)
Number of Cigarettes	0	52.0	1.00	1.00	25.6	1.00	1.00
	1-19	55.8	1.17 (0.60-2.25)	0.85 (0.40-1.77)	30.2	1.26 (0.62-2.58)	1.06 (0.48-2.33)
	20-35	63.5	1.60 (0.90-2.85)	1.01 (0.51-2.00)	38.1	1.79 (0.99-3.23)	1.30 (0.67-2.53)
	≥40	63.3	1.59 (0.73-3.50)	1.24 (0.48-3.18)	63.3	5.03 (2.26-11.2)	4.27 (1.69-10.77)
	p-trend		0.070	00.783		<0.001	0.010
Physical activity	High	55.7	1.00	1	25.0	1.00	1
	Moderate	56.2	1.02 (0.59-1.77)	0.89 (0.48-1.67)	32.2	1.43 (0.77-2.64)	1.64 (0.83-3.25)
	Low	55.6	0.99 (0.59-1.69)	1.11 (0.31-2.00)	35.1	1.62 (0.90-2.92)	1.75 (0.93-3.29)
Alcohol intake	No	53	1	1	31.5	1	1
	Yes	59	1.28 (0.84-1.96)	1.52 (0.90-2.55)	31.3	0.99 (0.63-1.56)	0.98 (0.57-1.69)
Total fat intake (% energy)	<30	54.8	1	1.00	30.6	1	1
	≥30	54.9	1.03 (0.57-1.74)	1.15 (0.62-2.13)	31.3	1.03 (0.57-1.87)	1.22 (0.34-2.35)
Saturated Fat (% energy)	<10	52.2	1	1	31	1	1
	≥10	56.3	1.17 (0.75-1.85)	1.73 (1.02-2.94)	31.3	1.01 (0.62-1.65)	1.01 (0.59-1.74)
Carbohydrates (% energy)	<55	53.8	1	1	30.8	1	1
	≥55	59.2	1.25 (0.73-2.12)	1.07 (0.59-1.93)	32.4	1.07 (0.61-1.88)	0.96 (0.52-1.76)
Sugar intake (% energy)	<10	54.8	1	1	32	1	1
	≥10	55.4	1.02 (0.57-1.82)	1.12 (0.59-2.16)	26.8	0.78 (0.41-1.48)	0.86 (0.43-1.73)
Protein intake (% energy)	<15	56.6	1	1	36.4	1	1
	≥15	53.6	0.88 (0.57-1.37)	0.83 (0.50-1.37)	27.3	0.66 (0.41-1.05)	0.79 (0.47-1.32)

*Controlling for age, gender, education, marital status, caloric intake and BMI

Table 2b Logistic regression analysis: associations of behavioral risks with very low-density lipoprotein (VLDL), low-density lipoprotein cholesterol (LDL-C) and high-density lipoprotein cholesterol (HDL-C).

		VLDL			LDL-C			HDL-C		
		%≥30 mg/dl	Crude OR (CI)	Adjusted* OR (CI)	%≥130 mg/dl	Crude OR (CI)	Adjusted* OR (CI)	%<40 mg/dl	Crude OR (CI)	Adjusted* OR (CI)
Number of Cigarettes	0	24.2	1.00	1	43.6	1.00	1	18.1	1.00	1.00
	1-19	27.9	1.21 (0.58-2.52)	1.01 (0.45-2.25)	53.5	1.49 (0.77-2.86)	1.12 (0.54-2.33)	18.6	1.04 (0.45-2.40)	1.01 (0.39-2.63)
	20-39	35.5	1.72 (0.94-3.14)	1.27 (0.64-2.51)	54.8	1.57 (0.89-2.76)	0.97 (0.50-1.89)	28.6	1.81 (0.95-3.45)	1.61 (0.75-3.45)
	≥40	56.7	4.09 (1.87-8.95)	3.26 (1.33-8.03)	53.3	1.48 (0.69-3.17)	0.96 (0.39-2.40)	40.0	3.02 (1.35-6.76)	1.98 (0.77-5.08)
	p-trend		<0.001	0.030		0.078	0.946		<0.001	0.106
Physical activity	High	26.1	1.00	1	48.9	1.00	1	27.3	1.00	1
	Moderate	28.9	1.15 (0.62-2.13)	1.27 (0.54-2.52)	49.6	1.02 (0.59-1.78)	0.89 (0.48-1.65)	19.0	0.62 (0.32-1.20)	0.93 (0.43-2.01)
	Low	32.0	1.33 (0.74-2.39)	1.44 (0.76-2.71)	46.0	0.89 (0.53-1.51)	0.93 (0.52-1.65)	21.2	0.72 (0.40-1.32)	0.69 (0.34-1.39)
Alcohol intake	No	28.3	1	1	43.4	1	1	20.5	1	1
	Yes	30.8	1.12 (0.71-1.79)	1.12 (0.65-1.93)	53.8	1.53 (1.00-2.33)	1.68 (1.01-2.82)	23.6	1.19 (0.72-1.98)	0.98 (0.54-1.78)
Total fat intake (% energy)	<30	29.0	1	1	45.2	1	1	25.8	1	1
	≥ 30	28.8	0.99 (0.54-1.82)	1.15 (0.59-2.22)	46.7	1.06 (0.61-1.85)	1.26 (0.69-2.33)	21.8	0.80 (0.42-1.52)	0.81 (0.39-1.65)
Saturated Fat (% energy)	<10	29.2	1	1	44.2	1	1	20.4	1	1
	≥ 10§	28.7	0.98 (0.59-1.61)	0.96 (0.56-1.66)	47.5	1.15 (0.72-1.80)	1.73 (1.02-2.93)	23.7	1.21 (0.70-2.16)	1.16 (0.62-2.17)
Carbohydrates (% energy)	<55	28.7	1	1	45.7	1	1	22.2	1	1
	≥55	29.6	1.04 (0.59-1.86)	0.96 (0.52-1.79)	49.3	1.16 (0.68-1.95)	0.93 (0.52-1.67)	23.9	1.10 (0.60-2.05)	1.18 (0.59-2.36)
Sugar intake (% energy)	<10	29.6	1	1	47.1	1	1	23.8	1	
	≥10	25.0	0.79 (0.41-1.53)	0.89 (0.44-1.82)	42.9	0.84 (0.47-1.50)	0.89 (0.47-1.71)	16.1	0.61 (0.28-1.31)	0.62 (0.26-1.45)
Protein intake (% energy)	<15	32.9	1	1	48.3	1	1	21	1	1
	≥15	25.9	0.71(0.44-1.15)	0.85 (0.50-1.44)	45.1	0.88 (0.57-1.36)	0.75 (0.46-1.24)	23.7	1.17 (0.59-1.97)	1.49 (0.82-2.72)

*Controlling for age, gender, education, marital status, caloric intake and BMI

BMJ Open

Prevalence and associations of behavioral risk factors with blood lipids profile in Lebanese adults: findings from the WHO STEPwise NCD cross-sectional Survey

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2018-026148.R3
Article Type:	Research
Date Submitted by the Author:	04-Jul-2019
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Primary Subject Heading:	Public health
Secondary Subject Heading:	Epidemiology, Nutrition and metabolism, Smoking and tobacco, Public health
Keywords:	PUBLIC HEALTH, EPIDEMIOLOGY, Cigarette Smoking, Blood lipids

Prevalence and associations of behavioral risk factors with blood lipids profile in Lebanese adults: findings from the WHO STEPwise NCD cross-sectional Survey

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Keywords: Cardiovascular disease, smoking, alcohol consumption, physical inactivity, dietary intake, blood lipids, Lebanon

Word count (excluding title page, abstract, references, and tables): 3143

Abstract

Objective: To examine associations of behavioral risk factors, namely cigarette smoking, physical activity, dietary intakes and alcohol consumption, with blood lipids profile.

Design and participants: Data drawn from a cross-sectional study involving participants aged 18 years and over (n = 363) from the nationwide WHO STEPwise Nutrition and Non-communicable Disease Risk Factor survey in Lebanon.

Measures: Demographic characteristics, behaviors and medical history were obtained from participants by questionnaire. Dietary assessment was performed using a 61-item culture-specific food frequency questionnaire that measured food intake over the past year. Lipid levels were measured by analysis of fasting blood samples (serum total cholesterol-TC, triglycerides-TG, very low-density lipoprotein-VLDL, low-density lipoprotein cholesterol-LDL-C and high-density lipoprotein cholesterol-HDL-C).

Results: Current cigarette smoking, alcohol consumption and low physical activity were prevalent among 33.3%, 39.7%, and 41.6% of the sample, respectively. The contributions of fat and saturated fat to daily energy intake were high, estimated at 36.5% and 11.4%, respectively. Abnormal levels of TC, TG, VLDL, LDL-C, and HDL-C were observed for 55.4%, 31.4%, 29.2%, 47.5% and 21.8% of participants, respectively. Adjusting for potential confounders, cigarette smoking was positively associated with higher odds of TG and VLDL (OR=4.27; 95% CI 1.69-10.77; and 3.26; 95% CI 1.33-8.03, respectively) with a significant dose-response relationship (p-value for trend=0.010 and 0.030, respectively). Alcohol drinking and high saturated fat intake (≥10% energy intake) were associated with higher odds of LDL-C (OR=1.68; 95% CI: 1.01-2.82 and OR= 1.73; 95% CI: 1.02-2.93). Physical activity did not associate significantly with any blood lipid parameter.

Conclusion: The demonstrated positive associations between smoking, alcohol drinking and high saturated fat intake with adverse lipoprotein levels lay further evidence for clinical

practitioners, public health professionals and dietitians in the development of preventive strategies among subjects with high risk of CVDs in Lebanon and other neighboring countries with similar epidemiological profile.

Strengths and limitations

- A nationwide survey administered in Lebanon, following the WHO STEPwise approach to surveillance guidelines, thus allowing for comparison with international literature.
- Low response rate (27.3%) for those who consented and gave fasting blood samples. Yet, differences between responders and non-responders were not significant on a number of socio-demographic characteristics.
- Whilst data on smoking, physical activity and dietary intakes were sufficiently detailed, measures of exposure to alcohol consumption lacked information on intensity and type and may be prone to misclassification bias.
- Attention to associations between behavioral factors and dietary intakes with intermediary metabolic conditions along the causal pathway for CVD informs work towards development of tailored preventive strategies for high risk individuals.

Introduction

The prevalence of cardiovascular diseases (CVD) is growing worldwide, and has reached epidemic levels, affecting both developed and developing countries.[1] The Middle East and North Africa countries represent a region which is now facing a fast rate of development and urbanization, with rates of chronic diseases increasing at an alarming rate and exceeding at times those of developed countries.[2] In Lebanon, a small middle-income country at the Eastern Mediterranean shore, data from the World Health Organization (WHO) indicate that the proportional mortality from CVD alone is 45%, making it the highest among all non-communicable diseases (NCDs).[3] With a population estimate of around 4.2 million and a Gross Domestic Product (GDP) of close to 8,520 US Dollars per capita, Lebanon is characterized by a high urbanization rate (87%), a growing trend towards survival in later life, coupled with westernization and modernization in diet and lifestyle and higher uptake of NCD risk factors.[4]

The primary goal in the prevention and management of CVD is to identify and modify the underlying risk behaviors that are amenable to intervention, namely, cigarette smoking, physical inactivity, dietary intakes and alcohol consumption. Associations between these factors and CVD risk through their effect on blood lipid levels have been widely examined in the western literature. Studies have shown that smokers are 2-4 times more at risk of developing heart disease than nonsmokers[5] and the number of cigarettes smoked/day independently predicts higher levels of Total Cholesterol (TC), Low Density Lipoprotein-Cholesterol (LDL-C), and Triglycerides (TG).[6] Also, smoking cessation has been shown to improve High Density Lipoprotein-Cholesterol (HDL-C) levels.[7] Cigarette smoking is described as a strong inflammation mediator and a key promoter in the atherosclerotic process. Similarly, the anti-inflammatory effect of frequent physical activity has been noted to be the reason behind reduced heart disease risk among physically active individuals.[8]

Regular physical activity with weight reduction has a large beneficial impact on the lipoproteins profile of adult men and women, [9] by increasing plasma volume, decreasing blood thickness, and thus reducing LDL-C concentrations. [10] Also, systematic reviews and meta-analysis of intervention studies have shown that heavy alcohol drinking results in an elevation in triglyceride levels, while moderate consumption increases circulating levels of HDL-C. [11] Similarly, diet is recognized as a modifiable risk factor that can make a substantial contribution to the risk of CVD. [12 13] Energy intake, the types of fatty acids consumed and the level of sugar ingestion may impact the lipid and cardiometabolic profile.[14] The 2017 Presidential Advisory from the American Heart Association indicated that replacement of saturated fat with unsaturated fatty acids decreases LDL-C levels and CVD risk, while replacing it with refined carbohydrates and sugar, yields no significant benefits to cardiovascular health. [14]

Much of the above evidence comes from studies conducted in North American and European countries and to a lesser extent from the Far East, mostly among Japanese and Korean population. Arab populations including the Lebanese have quite different risk behaviors, varied dietary habits and risk profile, [15] and studies evaluating the association between behaviors and intermediary variables along the causal pathway of CVD including lipid levels remain scarce in the region. Compared with other neighboring countries, Lebanon was shown to have one of the highest prevalence estimates of metabolic syndrome, [16] and has been witnessing high rates of smoking, among both adult men and women aged 18 years and over (42.9% and 27.5%, respectively).[17] Using data from a nationwide population-based survey of Lebanese adults, this study aims to examine the relation between behavioral risk factors including cigarette smoking, physical activity, dietary intakes and alcohol consumption with serum lipids and lipoproteins, while taking into account several potential confounding factors. Findings

from this study inform prevention strategies among subjects with high risk of CVD in the country.

Methods

Study design and participants

The data presented in this study are derived from the WHO Nutrition and Non-Communicable Diseases Risk Factor (NNCD-RF) cross-sectional household survey conducted in Lebanon in 2009. [18] Using multi-stage stratified cluster study design, the sampling was based on the age-sex distribution of the Lebanese population as provided by the Central Administration for Statistics. One adult was randomly selected from each household using Kish methodology. [19] Pregnant and lactating women and individuals with mental disabilities were excluded. With a non-response rate of 10% at the individual level, this yielded a sample of 2668 survey participants aged 18 years and above. Those free from known history of hyperlipidemia and diabetes in the first phase of the study (n = 1,331) were approached to undergo a biochemical assessment, of which 363 provided written consent and gave fasting blood samples. Further details on the design and sample of the survey are published elsewhere. [4] The study protocol was approved by the Institutional Review Board of the American University of Beirut (AUB), and informed consent was taken from all participants.

Data collection

The data collection procedure followed the WHO STEPwise approach to Surveillance, [20] and included the following three steps: Step 1 Questionnaire, whereby information about socio-demographic characteristics, NCDs and NCD risk factors, including dietary intake, were collected through face-to-face interviews; Step 2 in which anthropometric and blood pressure

measurements were taken using standardized techniques and calibrated equipment; and finally, Step 3 in which biochemical analysis for assessment of the blood lipid profile was performed on blood samples collected after an overnight fast of at least 8 hours. Serum was centrifuged on site and shipped on dry ice to the AUB Laboratory.

Measures of blood lipids

Levels of blood lipids including TC, TG, very low density lipoprotein (VLDL), LDL-C and HDL-C were analyzed using the Vitros 350 analyzer, an enzymatic spectrophotometric technique. The inter-assay variation of measurements did not exceed 4%. Quality control was performed within each run using standard performance verifier solutions provided by Ortho-Clinical Diagnostics. Analyses were conducted in duplicates, and the average value was utilized in the analysis. Based on the Adult Treatment Panel III guidelines,[21] the cutoff points used for the definition of risk levels of TC, TG, VLDL, LDL-C and HDL-C were ≥200, ≥150, ≥30, ≥130 and ≤40 mg/dl, respectively.

Behavioral risk factors and other measures

Behavioral risk factors examined in this study included cigarette smoking, physical activity, and alcohol consumption. Cigarette smoking status (never, past and current) and intensity (number of cigarettes smoked/day) were assessed. Intensity was later categorized into three levels according to number of cigarettes/day (1 to 19, 20 to 39 and ≥40). The short version of the International Physical Activity Questionnaire was used to assess physical activity among participants.[22] Three categories of physical activity (low, moderate, and high) were assigned based on METs-min/week (MET-min being the product of the resting metabolic rate for an activity and the number of minutes taken to perform it). Alcohol-related behavior was assessed as a dichotomous variable (ever vs never). Dietary assessment was performed using

a 61-item culture-specific food frequency questionnaire that measured food intake over the past year. [4, 15] Intakes of energy and macronutrients were estimated using the food composition database of the Nutritionist IV software, and the food composition table for local and traditional Middle-Eastern foods. [23,24] Intakes of carbohydrates, fat and protein were compared to cut-offs within the Acceptable Macronutrient Distribution Range, [25] and intakes of saturated fat and sugar were compared to the recommendations of the WHO. [26, 27]

Covariates of interest included total daily caloric intake and body mass index (BMI), measured as the ratio of weight (kilograms) to the square of height (meters). In addition, gender, age (18-29, 30-39, 40-49, 50-59, and ≥60), marital status (single, married, divorced/widowed), education level (complementary or less, secondary/technical, university and above), and occupational status (student/volunteer, working, does not work/housewife/retired) were considered as potential covariates.

Patient and Public Involvement

This study is based on secondary data analyses. The original data collection tool was adapted from the WHO STEPwise approach to NCD risk factor surveillance, [20] that did not directly involve patients or the public in outcome development or conduct of the study. However, we have been engaging with stakeholders to disseminate the findings on NCD risk factors, including tobacco consumption and dietary intakes, and on associations with various health-related outcomes to the public at large.

Statistical analysis

Means, standard deviations (SD) and frequencies were used to describe the various socio-demographic, behavioral, nutritional and clinical characteristics of the participants. The

associations between each of the risk factors and levels of the different blood lipids were examined using multiple logistic regression analysis. Unadjusted and adjusted odds ratios (ORs) and their 95% confidence intervals (CIs) controlling for age, gender, education, marital status, caloric intake and BMI were estimated. Test for trend with increasing number of daily amount of cigarettes smoked was also conducted, and a two-sided p-value < 0.05 was considered significant. The Statistical Package for the Social Sciences 22.0.1 (SPSS Inc., Chicago, IL, USA) was used for all computations.

Results

The socio-demographic and health-related characteristics of the study sample are summarized in Table 1. The sample was equally divided by gender (49.9% females and 50.1% males), with a mean age of 39.2 ± 15.2 years (range 18 to 92 years). The majority were married (60.6%), and close to half of the participants were employed (52.3%) at the time of the study, with a high percentage having less than complementary education (39.7%). Ever smokers constituted 37.5% of the sample, 41.6% were classified as being engaged in low-intensity physical activity, and 39.7% reported ever alcohol drinkers. Average daily energy intake was estimated at 2656 ± 1249 Kcal/day, with 36.5% of caloric intake from fat, 11.4%% from saturated fat, 49.1% from carbohydrates, 5.7% from sugar, and 15.2% from protein. Abnormal levels of TC, TG, VLDL, LDL-C, and HDL-C were observed for 55.4%, 31.4%, 29.2%, 47.5% and 21.8% of the participants, respectively.

Insert table 1 around here

Tables 2a and 2b show the unadjusted and adjusted ORs for the association between behavioral risk factors and dietary variables with blood lipids levels. Associations with cigarette smoking were positive for most outcomes but significant for those consuming more than 40 cigarettes/day, compared to non-smokers, in the case of TG (unadjusted OR = 5.03) and VLDL (OR = 4.09) and HDL-C OR = 3.02). Adjusting for potential confounders, the associations maintained statistical significance for TG and VLDL, with an adjusted OR of 4.27 (95% CI 1.69- 10.77) and 3.26 (95% CI 1.33-8.03), respectively. Results showed a dose-response relationship with increasing number of cigarettes consumed for (p-value for trend = 0.010 and 0.030, respectively). In addition, a statistically significant association was observed between ever alcohol drinking and LDL-C (OR=1.53). This association retained statistical significance even after adjustment for potential confounders with an OR of 1.68 (95% CI 1.01-2.82). Out of all the dietary variables examined, only saturated fat was associated with blood lipids, namely TC and LDL-C, with an adjusted OR of 1.73 for both lipid abnormalities (95% CI 1.02-2.94 and 1.02-2.93, respectively). Physical activity was not associated with any of the blood lipid parameters.

Insert tables 2a and 2b around here

Discussion

Our results showed that heavy cigarette smoking is associated with increased levels of TG and VLDL, with findings showing significant dose-response relationships with increasing number of cigarettes smoked per day. The study also showed that alcohol drinking and high saturated fat intake are significantly associated with higher levels of LDL-C. However, there were no consistent associations between physical activity and fasting blood lipids profile. To

our knowledge, this is the first study in Lebanon to explore these associations, based on objectively measured lipid parameters and using standardized laboratory techniques and tools, while taking into consideration the effect of potential confounders.

There are strong indicators in the literature that the deleterious effect of cigarette smoking on heart disease and atherosclerosis is partially explained by the effect of smoking on the concentration of blood lipids and lipoproteins. Our study confirms the results of earlier cross-sectional studies showing that the association between smoking and lipoproteins are observed in the levels of TG, VLDL and HDL-C, [6, 28, 29] with the impact on lipid levels increasing with increase in the number of cigarettes smoked/day in a dose dependent relationship. [30, 31] Our observation of the largest effect of cigarette smoking on lipid parameters being seen in those who smoked more than two packs a day is also consistent with Chen et al. study comprising of 1,164 men in Taiwan. [32] One popular mechanism by which smoking affects lipoproteins is that cigarette particulate matter alters catecholamine release—and thus free fatty acid release, which in turn contributes to the accumulation of the LDL-C concentrations and to lower levels of HDL-C in the blood. [33] The association between cigarette smoking and the increase in TG can also be explained by the decrease in the activity of the lipoprotein lipase among smokers thus disrupting lipid and lipoprotein metabolism. Furthermore, smoking cessation was found to improve lipid and lipoprotein levels in observational studies and randomized clinical trials. [7, 34] Taken together, the totality of evidence from these studies and our data-including consistency upon replication across various studies, the dose-response relationship, the magnitude and significance of association, biological plausibility as well as effects of smoking cessation on lipoprotein levels, supports a strong relationship between smoking and lipid profiles.

Our study showed that alcohol drinking was associated with higher LDL-C levels in Lebanese adults but was not associated with other lipid parameters. Available evidence on the impact of alcohol on LDL-C is conflicting with recent studies suggesting that the association of alcohol and LDL-C levels may be population-specific. [35] For instance, studies conducted amongst Danish adults reported an inverse association between alcohol intake and LDL-C, [36] while studies conducted in Spanish and Italian populations found that higher alcohol consumption was associated with increased LDL-C. [37, 38] According to a review by Brinton (2012), these inconsistent findings on the association between alcohol intake and LDL-C, may be explained by allele-specific genetic effects, such as the Apo E4 and Apo A5 genes.[, 39] In our study, alcohol drinking was not associated with HDL-C levels. Findings on the relationship between alcohol and HDL-C have in fact been less consistent in the literature, with some but not all showing an effect on higher HDL-C levels. [40, 41] Indeed, the effect of alcohol on CVD including coronary artery disease, stroke and myocardial infarction appears to be biphasic showing a J or U-shaped relationship based on the amount of alcohol consumed, [41, 42] with lower CVD mortality risks by light to moderate alcohol consumption and increased risk by heavy alcohol intake.[43] The discrepancy between our results with those in the literature may be due to differences in race/ethnicity and genetic variations. [44] Alternatively, it may be due to the definition of alcohol exposure adopted in our study which was based on a dichotomous variable (ever vs never), and thus does not capture alcohol intake in terms of frequency, intensity, types and pattern of alcohol consumed. It is important to also acknowledge that alcohol consumption may be subject to reporting bias in the Lebanese society due to cultural or religious norms. The observed association between alcohol and lipid profile should therefore be interpreted with caution, as it may have been the artifact of other social or lifestyle factors that were not measured in our study.

Dietary intakes are amongst the modifiable risk factors that may modulate plasma lipids and the risk of CVD. In our study, saturated fat was the only dietary factor that was significantly associated with lipid parameters, and specifically with TC and LDL-C. Despite the increasing controversy around the relationship between saturated fat and blood cholesterol levels, an increasing body of evidence highlights the strong atherogenicity of saturated fatty acids through their impact on LDL-C. [14] A systematic review and meta-regression analysis published in 2016 showed that a decrease in saturated fats of 1% of daily energy intake coupled with an increase of 1% in polyunsaturated fat, lowered LDL cholesterol by 2.1 mg/dL.[45] In 2017, a Presidential Advisory from the American Heart Association (AHA) concluded that available evidence strengthens the long-standing AHA recommendations to decrease saturated fat intake and replace it with unsaturated fats. The AHA Advisory highlighted that the shift from saturated to unsaturated fats should occur in the context of an overall healthful dietary pattern such as the DASH or Mediterranean patterns. [14]

In our study, physical activity did not appear to be associated with lipid parameters. The literature suggests that physical activity increases the level of HDL-C and has beneficial effects on lipoprotein particle size and number. [46] Also, moderate intensity exercise is known to have a more favorable effect on blood lipids since it allows the use of lipids as a fuel source which implies an increase in the uptake and oxidation of the lipids in the skeletal muscle. [46]

Some other limitations should be taken into consideration when interpreting the results of our study. Because the study used a cross-sectional design, findings only imply associations and causal relationships cannot be established. The proportion of participants who gave fasting blood samples (of at least 8 hours) was relatively small (27.3%); however, responders were comparable to non-responders on a number of socio-demographic characteristics except for

marital status (61% of responders vs. 50% of non-responders were married). Also, we had earlier documented comparable dietary data between respondents and non-respondents based on factor loading matrices on patterns of food groups intake. [4] As mentioned earlier, measures of exposure were self-reported which can introduce some misclassification error. This may have been particularly problematic in the case of alcohol consumption, given that our definition based on a dichotomous variable of "ever" vs "never" does not allow for the assessment of drinking frequency and patterns or the type of alcohol consumed. In contrast, our measurement of cigarette smoking and physical activity were more detailed and reliable. Information on cigarette smoking in our study included the amount of cigarettes smoked and the standardized IPAQ was used to assess physical activity.

To conclude, our results suggest that smoking, alcohol drinking and high saturated fat are associated with adverse levels of lipoprotein, among Lebanese men and women. There is enough evidence in the literature indicating the role of lipoproteins in atherogenesis and that controlling for blood lipid levels decreases the risk of heart and many other chronic diseases. Our findings lay further evidence for clinical practitioners, public health professionals and dieticians regarding the potential benefits of lifestyle and dietary modifications in their pursuit to curb the burden of hyperlipidemia and CVD at the individual and population level. The overall high rate of smoking behavior in Lebanon among both men and women, coupled with the shift in dietary patterns towards high fat energy dense foods, [7, 15] are likely to adversely impact on the healthcare bill in the country. Further studies with larger sample size that examine the association of combination patterns of poor lifestyle factors on lipid profile among Lebanese adults are warranted.

Contributors

MM conducted initial analyses and wrote the first draft, in partial fulfillment of her MSc in Epidemiology. HT supervised the conduct of analyses and contributed to the write-up. LN conducted the dietary analyses and contributed to the write-up and revisions. CK, NH, MC and AF provided statistical advice and contributed to the paper revisions. AMS coordinated original study conduct, conceived and finalized the analyses, and contributed substantially to the write-up and revisions. All authors read and approved the final version of the manuscript.

Funding statement

The original study conduct was funded by the World Health Organization (WHO) - Lebanon. However, no funds were available for this secondary analysis.

Data sharing statement

The dataset was available for all authors of the study and will be available for other non-commercial researchers upon request.

Declaration of conflicting interests

The authors declare that there is no conflict of interest.

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Table 1 Distribution of socio-demographic characteristics, behavioral factors and lipid profile of the study population.

	n	%
Gender (% female)	181	49.9
Age (mean ± SD, years)	39.2 ± 15.2	
18-29	113	31.1
30-39	106	29.2
40-49	67	18.5
50-59	32	8.8
≥60	45	12.4
Marital Status		
Single	128	35.3
Married	220	60.6
Divorced/widowed	15	4.1
Work Status		
Student or volunteer	31	8.5
Employed	190	52.3
Does not work/housewife/retired	142	39.1
Educational Level		
Complementary or less	144	39.7
Secondary or technical	99	27.3
University and above	120	33.1
Cigarette Smoking		
Never smoked	227	62.5
Past smoker	15	4.2
Current smoker	121	33.3
Number of cigarettes smoked/day		
0	227	62.5
1-19	43	11.8
20-39	63	17.4
≥40	30	8.3
Physical activity		
Low-intensity activity	151	41.6
Moderate-intensity activity	121	33.3
High-intensity activity	88	24.2
Alcohol consumption (ever drinker)	144	39.7
Total caloric intake (mean ± SD, Kcal/day)	2656 ± 1249	
Fat intake (% of total energy) [a]	36.5 ± 6.89	
≥ 30 [b]	275	81.6
Saturated fat intake (% of total energy) [a]	11.4 ± 2.92	
≥10 [c]	224	66.5
Carbohydrates intake (% of total energy) [a]	49.1 ± 7.03	
≥55 [b]	71	21.1
Sugar (% of total energy) [a]	5.7 ± 4.64	
≥ 10 [d]	56	16.6
Proteins intake (% of total energy) [a]	152 ± 2.91	
<15 [b]	143	42.4
Total Cholesterol (mean ± SD, mg/dl)	210 ± 45	
% Elevated total cholesterol (≥200 mg/dl) [e]	201	55.4
Triglycerides (mean ± SD, mg/dl)	138 ± 78	
% Elevated triglycerides (≥150 mg/dl) [e]	114	31.4

VLDL (mean ± SD, mg/dl)	27 ± 15	
% Elevated VLDL (≥30 mg/dl) [e]	106	29.2
LDL-C (mean ± SD, mg/dl)	131 ± 39	
% Elevated LDL-C (≥130 mg/dl) [e]	172	47.5
HDL-C (mean ± SD, mg/dl)	51 ± 14	
% Reduced HDL-C (≤40 mg/dl) [e]	79	21.8

[a] Dietary variables are based on a sample of 337 subjects owing to missing data
[b] Macronutrient cutoffs are within the Acceptable Macronutrient Distribution Range (AMDR) [25]
[c] Saturated fat cutoff based on the WHO recommendations [26]
[d] Sugar intake cutoff based on the WHO recommendations [27]
[e] Lipid cutoff values based on the Adult Treatment Panel III guidelines [21] ;Very Low Density Lipoprotein (VLDL); Low Density Lipoprotein cholesterol (LDL-C); High Density Lipoprotein cholesterol (HDL-C)

Table 2a Logistic regression analysis: associations of behavioral risks with total cholesterol (TC) and triglycerides (TG)

		TC			TG		
		% ≥200 mg/dl	Crude OR (CI)	Adjusted* OR (CI)	% ≥150 mg/dl	Crude OR (CI)	Adjusted* OR (CI)
Number of Cigarettes	0	52.0	1.00	1.00	25.6	1.00	1.00
	1-19	55.8	1.17 (0.60-2.25)	0.85 (0.40-1.77)	30.2	1.26 (0.62-2.58)	1.06 (0.48-2.33)
	20-35	63.5	1.60 (0.90-2.85)	1.01 (0.51-2.00)	38.1	1.79 (0.99-3.23)	1.30 (0.67-2.53)
	≥40	63.3	1.59 (0.73-3.50)	1.24 (0.48-3.18)	63.3	5.03 (2.26-11.2)	4.27 (1.69-10.77)
	p-trend		0.070	00.783		<0.001	0.010
Physical activity	High	55.7	1.00	1	25.0	1.00	1
	Moderate	56.2	1.02 (0.59-1.77)	0.89 (0.48-1.67)	32.2	1.43 (0.77-2.64)	1.64 (0.83-3.25)
	Low	55.6	0.99 (0.59-1.69)	1.11 (0.31-2.00)	35.1	1.62 (0.90-2.92)	1.75 (0.93-3.29)
Alcohol intake	No	53	1	1	31.5	1	1
	Yes	59	1.28 (0.84-1.96)	1.52 (0.90-2.55)	31.3	0.99 (0.63-1.56)	0.98 (0.57-1.69)
Total fat intake (% energy)	<30	54.8	1	1.00	30.6	1	1
	≥30	54.9	1.03 (0.57-1.74)	1.15 (0.62-2.13)	31.3	1.03 (0.57-1.87)	1.22 (0.34-2.35)
Saturated Fat (% energy)	<10	52.2	1	1	31	1	1
	≥10	56.3	1.17 (0.75-1.85)	1.73 (1.02-2.94)	31.3	1.01 (0.62-1.65)	1.01 (0.59-1.74)
Carbohydrates (% energy)	<55	53.8	1	1	30.8	1	1
	≥55	59.2	1.25 (0.73-2.12)	1.07 (0.59-1.93)	32.4	1.07 (0.61-1.88)	0.96 (0.52-1.76)
Sugar intake (% energy)	<10	54.8	1	1	32	1	1
	≥10	55.4	1.02 (0.57-1.82)	1.12 (0.59-2.16)	26.8	0.78 (0.41-1.48)	0.86 (0.43-1.73)
Protein intake (% energy)	<15	56.6	1	1	36.4	1	1
	≥15	53.6	0.88 (0.57-1.37)	0.83 (0.50-1.37)	27.3	0.66 (0.41-1.05)	0.79 (0.47-1.32)

*Controlling for age, gender, education, marital status, caloric intake and BMI

Table 2b Logistic regression analysis: associations of behavioral risks with very low-density lipoprotein (VLDL), low-density lipoprotein cholesterol (LDL-C) and high-density lipoprotein cholesterol (HDL-C).

		VLDL			LDL-C			HDL-C		
		%≥30 mg/dl	Crude OR (CI)	Adjusted* OR (CI)	%≥130 mg/dl	Crude OR (CI)	Adjusted* OR (CI)	%<40 mg/dl	Crude OR (CI)	Adjusted* OR (CI)
Number of Cigarettes	0	24.2	1.00	1	43.6	1.00	1	18.1	1.00	1.00
	1-19	27.9	1.21 (0.58-2.52)	1.01 (0.45-2.25)	53.5	1.49 (0.77-2.86)	1.12 (0.54-2.33)	18.6	1.04 (0.45-2.40)	1.01 (0.39-2.63)
	20-39	35.5	1.72 (0.94-3.14)	1.27 (0.64-2.51)	54.8	1.57 (0.89-2.76)	0.97 (0.50-1.89)	28.6	1.81 (0.95-3.45)	1.61 (0.75-3.45)
	≥40	56.7	4.09 (1.87-8.95)	3.26 (1.33-8.03)	53.3	1.48 (0.69-3.17)	0.96 (0.39-2.40)	40.0	3.02 (1.35-6.76)	1.98 (0.77-5.08)
	p-trend		<0.001	0.030		0.078	0.946		<0.001	0.106
Physical activity	High	26.1	1.00	1	48.9	1.00	1	27.3	1.00	1
	Moderate	28.9	1.15 (0.62-2.13)	1.27 (0.54-2.52)	49.6	1.02 (0.59-1.78)	0.89 (0.48-1.65)	19.0	0.62 (0.32-1.20)	0.93 (0.43-2.01)
	Low	32.0	1.33 (0.74-2.39)	1.44 (0.76-2.71)	46.0	0.89 (0.53-1.51)	0.93 (0.52-1.65)	21.2	0.72 (0.40-1.32)	0.69 (0.34-1.39)
Alcohol intake	No	28.3	1	1	43.4	1	1	20.5	1	1
	Yes	30.8	1.12 (0.71-1.79)	1.12 (0.65-1.93)	53.8	1.53 (1.00-2.33)	1.68 (1.01-2.82)	23.6	1.19 (0.72-1.98)	0.98 (0.54-1.78)
Total fat intake (% energy)	<30	29.0	1	1	45.2	1	1	25.8	1	1
	≥ 30	28.8	0.99 (0.54-1.82)	1.15 (0.59-2.22)	46.7	1.06 (0.61-1.85)	1.26 (0.69-2.33)	21.8	0.80 (0.42-1.52)	0.81 (0.39-1.65)
Saturated Fat (% energy)	<10	29.2	1	1	44.2	1	1	20.4	1	1
	≥ 10§	28.7	0.98 (0.59-1.61)	0.96 (0.56-1.66)	47.5	1.15 (0.72-1.80)	1.73 (1.02-2.93)	23.7	1.21 (0.70-2.16)	1.16 (0.62-2.17)
Carbohydrates (% energy)	<55	28.7	1	1	45.7	1	1	22.2	1	1
	≥55	29.6	1.04 (0.59-1.86)	0.96 (0.52-1.79)	49.3	1.16 (0.68-1.95)	0.93 (0.52-1.67)	23.9	1.10 (0.60-2.05)	1.18 (0.59-2.36)
Sugar intake (% energy)	<10	29.6	1	1	47.1	1	1	23.8	1	
	≥10	25.0	0.79 (0.41-1.53)	0.89 (0.44-1.82)	42.9	0.84 (0.47-1.50)	0.89 (0.47-1.71)	16.1	0.61 (0.28-1.31)	0.62 (0.26-1.45)
Protein intake (% energy)	<15	32.9	1	1	48.3	1	1	21	1	1
	≥15	25.9	0.71(0.44-1.15)	0.85 (0.50-1.44)	45.1	0.88 (0.57-1.36)	0.75 (0.46-1.24)	23.7	1.17 (0.59-1.97)	1.49 (0.82-2.72)

*Controlling for age, gender, education, marital status, caloric intake and BMI