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Lipid Distribution Differentials among Smokers, Non-Smokers and within Various Types of Smokers

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Abstract

Data from National Health and Nutrition Examination Survey for those aged ≥ 20 years fasting for at least 8 hours for the years 1999-2012 were used to evaluate adjusted and unadjusted differences in the levels of low-density-lipoprotein-cholesterol (LDL), high-density-lipoprotein-cholesterol (HDL), total cholesterol (TC), and triglyceride (TG) among self-reported current smokers and nonsmokers as well as smokers smoking cigarettes, pipes, cigars etc. Adjustments were made for the effects of gender; race/ethnicity; dietary intake of alcohol, caffeine, fatty acids, saturated and total fat; fasting time; body mass index; and frequency and intensity of smoking during the last five days. Adjusted levels of LDL, TC, and TG did not vary among smokers and nonsmokers but contrary to what could be expected, smokers were observed to have high HDL levels than nonsmokers (52.2 vs. 50.1 mg/dL, $p=0.02$). However, in the unadjusted analysis, smokers were found to have lower levels of HDL (48.2 vs. 52.1 mg/dL, $p<0.01$) and higher levels of TG (123.2 vs. 113.5 mg/dL, $p<0.01$) than nonsmokers but the differences for LDL (112.9 vs. 112.5 mg/dL, $p=0.68$) and TC (193.4 vs. 194.3 mg/dL, $p=0.39$) remained statistically insignificant. Adjusted levels of HDL, TC, and LDL levels did not differ among exclusive cigarette and cigar users and exclusive tobacco chewers and snuffers. Exclusive cigarette and cigar users had higher adjusted levels of TG than exclusive tobacco snuffers (125.7 and 133.8 vs. 101.5 mg/dL, $p<0.01$).

Keywords: Smoking; Triglyceride; Cholesterol; Lipids; Lipoprotein

Introduction

Lipid profile differentials among smokers and nonsmokers have been evaluated by several authors. Among Japanese males aged 24-68 years, smokers with Brinkman Index ≥ 554 (defined as the number of cigarettes smoked per day multiplied by duration of smoking in years) were found to have 1.657 times the odds of having abnormal triglyceride (TG) levels than nonsmokers ($p=0.04$) but the odds of having

abnormal levels of total cholesterol (TC) and high density lipoprotein cholesterol levels (HDL) were not statistically significantly different among smokers and nonsmokers. In another Japanese study among males aged 42-81 years, among those who had visceral area ≥ 100 cm², proportion of subjects with TG ≥ 150 mg/dL was 47.3%, 36.4%, and 18.8% among current smokers, former smokers, and nonsmokers respectively. However, TG levels were not found to differ among current smokers, former smokers, and non-smokers when visceral area was <100 cm². Thus, an interaction between smoking and body fat distribution was found to affect TG levels. Based on across-sectional study of 103,648 Japanese males and females aged 17-94 years, (i) TC levels were lower for smokers than nonsmokers among males aged ≥ 25 years and among females aged 35-64 years, (ii) LDL levels were lower for smokers than nonsmokers among males aged 25-64 years and ≥ 75 years and among females aged 25-44 years, (iii) HDL levels were lower for smokers than nonsmokers among males aged 25-74 years and among females aged 17-64 years, and (iv) TG levels were higher for smokers than nonsmokers among males aged 25-74 years and among females aged 17-64 years. It should be noted that results reported by Kuzuya et al. [1] were based on unadjusted analysis and the results for TC, LDL, and HDL were in direct contradiction to what has been reported by other authors but the results for TG levels paralleled those of the other authors [2].

Based on a study of 100 gender and age matched smokers and nonsmokers conducted in India [3], smokers smoking 10-15 cigarettes per day for 1-5 years, 16-20 cigarettes a day for 6-10 years, and >20 cigarettes a day for >10 years were all found to have higher levels of TC, TG, LDL, and VLDL and lower levels of HDL when compared with nonsmokers. Gogania and Hemeshwar reported smokers and smokers who also chewed tobacco to have statistically significantly higher levels of TG ($p<0.01$), and VLDL ($p<0.01$) and lower levels of HDL ($p<0.01$) than nonsmokers and, in addition, smoker who also chewed tobacco had statistically significantly higher levels of TC ($p<0.01$) and LDL ($p<0.01$). Among mild, moderate, heavy smokers, and nonsmokers aged 40-59 years, TC levels were reported to be 198, 224, 240, and 160 mg/dL respectively; TG levels were: 164, 199, 223, and 124 mg/dL respectively; LDL levels were: 94, 104, 120, and 82 mg/dL respectively; and HDL levels were: 42,39,35 and 48 mg/dL respectively [4].

Based on the review of 54 published studies, when compared with nonsmokers, smokers were found to higher levels of TC by 3%, TG levels by 9.1%, very low density lipoprotein levels (VLDL) by 10%, and LDL by 1.7% and lower levels of HDL by 5.7%. A dose response association was also reported among nonsmokers, light, moderate, and heavy smokers [5] reported levels of VLDL, LDL, TG, and TC to be substantially higher and the levels of HDL to be substantially lower among smokers when compared with nonsmokers but, while among females, the main impact of smoking was on TG levels, in males, smoking had little impact on triglycerides and affected HDL more directly [6]. Reported smoking females with non-type 2 diabetes and smoking males with type 2 diabetes to have higher levels of TG than nonsmokers [7], however, no association between the number of metabolic syndrome which included HDL and TG and smoking [8] reported association between increased TG levels and smoking among elderly people aged ≥ 60 years. Smoking was not found to alter lipid profile among schizophrenic patients [9]. Increased levels of TC ($p=0.009$), LDL ($p=0.023$), and TG ($p=0.002$) were associated with increases in number of cigarettes smoked per day.

Among post-menopausal females aged 40-59 years old, current smokers as compared to never smokers were found to have higher levels of LDL ($p=0.01$), TC ($p=0.001$), and TG ($p=0.001$) but this association was not observed among pre-menopausal females [10].

Among adolescents aged 12-19 years, lipid profile among those exposed to second hand smoke (SHS) and those not exposed to SHS was not found to differ. However, among active smokers, differences in TG levels, the ratio of TG to HDL and LDL levels among those exposed to SHS and not exposed to SHS were observed [11].

A possible mechanism of how cigarette smoking may alter lipid levels in serum/plasma is provided by Devaranavadgi et al. Lipid composition of various types of cured tobacco leaves and cigarette smoke condensate is provided by Dunkle et al. [12].

Not many of the studies mentioned above seem to have been conducted on a nationally representative sample of subjects and, in addition, to the best of my knowledge, there have been no studies (other than the ones mentioned above)

that have investigated the variability in lipid profiles among smokers smoking cigarettes, pipes, cigars, and others including dual use smokers who use more than one type of smoking. Consequently, the primary objective of this study was to evaluate how levels of HDL, LDL, TC, and TG vary among single and dual use smokers when adjustments are made for gender, race/ethnicity, and other covariates as detailed in the next section. A second objective of the study was to evaluate lipid profile differentials among all smokers and nonsmokers. Data for the years 1999-2012 for those aged ≥ 20 years from National Health and Nutrition Examination Survey (NHANES, www.cdc.gov/nchs/nhanes.htm) were selected to conduct this study. Data from NHANES were selected because NHANES provides data for a nationally representative sample of non-institutionalized US population.

Materials and Methods

Data source and description

Data from NHANES (www.cdc.gov/nchs/nhanes.htm) for the years 1999-2012 for those ≥ 20 years old who have fasted for at least 8 hours prior to blood draw on demographics, body measures, physical activity, mobile examination center (MEC) smoking questionnaire, total nutrient intake, HDL, LDL, TC, and TG levels were downloaded and match merged.

Sample size

Unweighted sample size for those ≥ 20 years old who have fasted for at least 8 hours prior to blood draw was 15267. Among 15267 participants, 10739 reported being nonsmokers, 3497 reported being current smokers, and 1031 did not report their smoking status. Of 3497 smokers, because of small sample sizes, 13 smokers who reported being triple smokers and/or dual smokers without being cigarette smokers were removed from the study because of very small sample sizes. Of the remaining 3484 smokers, 3417 were single use smokers, and 67 were dual use smokers. Details are given in **Table 1**. However, for some of the analyses conducted, the sample sizes were somewhat smaller because of missing values for physical activity levels and other variables. In addition, for the adjusted analysis, all dual use smokers were treated as mixed dual use smokers (**Table 1**).

Table 1 Weighted and unweighted sample sizes by mode of smoking by gender and race/ethnicity. Data from National Health and Nutrition Examination Survey 1999-2012.

Demographic Group	Mode of Smoking	Unweighted	Weighted	Weighted Percent
Total	Cigarettes Only	2971	309687810	83.7
	Pipes only	25	2634779	0.7
	Cigars only	198	21101237	5.7
	Chewing tobacco only	144	17117803	4.6
	Snuffing tobacco only	79	10959742	3.0

	Cigarettes and cigars*	30	3119389	0.8
	Cigarettes and chewing tobacco*	21	2628390	0.7
	Cigarettes and snuffing tobacco*	16	2563008	0.7
Males	Cigarettes Only	1697	170152463	75.4
	Pipes only	22	2212479	1.0
	Cigars only	178	18938234	8.4
	Chewing tobacco only	130	16394794	7.3
	Snuffing tobacco only	68	10157032	4.5
	Cigarettes and cigars*	26	2740819	1.2
	Cigarettes and chewing tobacco*	21	2628390	1.2
	Cigarettes and snuffing tobacco*	16	2563008	1.1
Females	Cigarettes Only	1274	139535347	96.9
	Pipes only	3	422300	0.3
	Cigars only	20	2163003	1.5
	Chewing tobacco only	14	723010	0.5
	Snuffing tobacco only	11	802710	0.6
	Cigarettes and cigars*	4	378570	0.3
	Cigarettes and chewing tobacco*	0	0	0.0
	Cigarettes and snuffing tobacco*	0	0	0.0
Non-Hispanic Whites	Cigarettes Only	1497	219244046	82.2
	Pipes only	22	2453434	0.9
	Cigars only	92	13073191	4.9
	Chewing tobacco only	112	15187968	5.7
	Snuffing tobacco only	59	9877757	3.7
	Cigarettes and cigars*	11	1880244	0.7
	Cigarettes and chewing tobacco*	19	2536802	1.0
	Cigarettes and snuffing tobacco*	15	2500582	0.9
Non-Hispanic Blacks	Cigarettes Only	672	39172251	83.3
	Pipes only	0	0	0.0
	Cigars only	79	5156929	11.0
	Chewing tobacco only	22	1140830	2.4
	Snuffing tobacco only	12	557180	1.2
	Cigarettes and cigars*	17	1012921	2.2
	Cigarettes and chewing tobacco*	0	0	0.0
	Cigarettes and snuffing tobacco*	0	0	0.0
Mexican Americans	Cigarettes Only	460	19580798	95.4
	Pipes only	1	39701	0.2
	Cigars only	8	355779	1.7
	Chewing tobacco only	5	103865	0.5

	Snuffing tobacco only	6	344136	1.7
	Cigarettes and cigars*	0	0	0.0
	Cigarettes and chewing tobacco*	1	28693	0.1
	Cigarettes and snuffing tobacco*	1	62426	0.3
Other Race/Ethnicities	Cigarettes Only	342	31690715	89.3
	Pipes only	2	141644	0.4
	Cigars only	19	2515337	7.1
	Chewing tobacco only	5	685141	1.9
	Snuffing tobacco only	2	180669	0.5
	Cigarettes and cigars*	2	226223	0.6
	Cigarettes and chewing tobacco*	1	62894	0.2
	Cigarettes and snuffing tobacco*	0	0	0.0

*collapsed together for adjusted analyses.

Derived variables

Self-reported levels of recreational physical activity were categorized as vigorous, moderate, none or minimal. For the years 1999-2006, participants were asked if they were engaged in (a) vigorous recreational activity for at least 10 minutes during the last 30 days that lead to heavy sweating or large increase in breathing or heart rate and (b) moderate activity for at least 10 minutes during the last 30 days that lead to only slight sweating or a slight to moderate increase in breathing or heart rate. For the years 2007-2012, instead of being asked about the activity during the last 30 days, activity status was enquired during a typical week. Those who self-reported being engaged in vigorous activity with or without being engaged in moderate activity were classified as being engaged in vigorous activity. Those who self-reported being engaged in moderate activity without being engaged in vigorous activity were classified as being engaged in moderate activity. Those who did not answer question about their recreational physical

activity were considered to be engaged in minimal or no physical activity.

Software

SAS University Edition software was used to analyze data for this study.

Statistical analyses

Unadjusted geometric means with 95% confidence intervals for HDL, LDL, TC, and TG levels by gender and race/ethnicity for each type of smoking, namely, cigarette only, pipe only, cigar only, tobacco chewers only, tobacco snuffers only, cigarette and cigar smokers, cigarette users and tobacco chewers, and cigarette smokers and tobacco snuffers were computed by SAS Proc SURVEYREG and are given in **Table 2** and p-values for pairwise comparisons are given in **Table 3**.

Table 2 Unadjusted geometric mean fasting levels of high density lipoprotein (HDL), low density lipoprotein (LDL), triglyceride in mg/dL with 95% confidence intervals by gender and race/ethnicity for those aged ≥ 20 years by mode of smoking. Data from National Health and Nutrition Examination Survey 1999-2012.

	Smoking Mode	HDL in mg/dL	LDL in mg/dL	Total Cholesterol in mg/dL	Triglyceride in mg/dL
Total	Cigarettes Only	48.4 (47.6-49.1)	112.7 (111-114.4)	193.6 (191.5-195.7)	123.2 (120.2-126.4)
	Pipes only	49.1 (46-52.4)	107 (96.8-118.2)	181.2 (169.1-194.2)	99.6 (77.6-127.8)
	Cigars only	48.6 (46.5-50.8)	115.1 (108.8-121.8)	197 (189.4-205)	129 (117.6-141.5)
	Chewing tobacco only	44.5 (42.5-46.6)	116.9 (110.4-123.8)	192.3 (185.5-199.3)	126.1 (114.8-138.4)
	Snuffing tobacco only	48.4 (43.2-54.1)	112.7 (102.7-123.7)	191.2 (179.6-203.6)	112.8 (98.2-129.7)
	Cigarettes and cigars	50.3 (47.2-53.7)	121.5 (102.5-143.9)	198.7 (176-224.4)	110.5 (88.3-138.2)
	Cigarettes and chewing tobacco	43.3 (37.3-50.3)	101.9 (82.7-125.6)	182.8 (164.8-202.7)	133.2 (86.1-206.1)
	Cigarettes and snuffing tobacco	45.1 (38.6-52.7)	101.6 (90.6-113.8)	182.4 (168.9-197)	139 (94-205.5)

Males	Cigarettes Only	45.9 (45.1-46.7)	112.5 (110.4-114.6)	191.7 (189.2-194.3)	126.8 (122.6-131.2)
	Pipes only	48.3 (45.1-51.7)	109 (97.5-121.8)	184.9 (171.4-199.5)	111.2 (86.6-142.9)
	Cigars only	47.2 (45.3-49.2)	115.2 (109.4-121.3)	197 (190.3-204)	136.9 (124.8-150.2)
	Chewing tobacco only	44.2 (42.2-46.3)	116.2 (109.7-123.2)	191.1 (184.2-198.2)	126.9 (115.2-139.7)
	Snuffing tobacco only	46.8 (42.4-51.6)	113.2 (102.3-125.4)	190.2 (177.7-203.5)	115.5 (100.3-133)
	Cigarettes and cigars	50.5 (47.8-53.4)	120.8 (99.8-146.1)	198 (172.5-227.1)	111.7 (87.5-142.6)
	Cigarettes and chewing tobacco	43.3 (37.3-50.3)	101.9 (82.7-125.6)	182.8 (164.8-202.7)	133.2 (86.1-206.1)
	Cigarettes and snuffing tobacco	45.1 (38.6-52.7)	101.6 (90.6-113.8)	182.4 (168.9-197)	139 (94-205.5)
Females	Cigarettes Only	51.6 (50.5-52.6)	113 (110.5-115.6)	195.8 (192.8-198.9)	118.9 (114.9-123.1)
	Pipes only	53.6 (50.2-57.3)	96.9 (84.4-111.3)	162.9 (151.9-174.7)	55.8 (50.9-61.1)
	Cigars only	63 (54.8-72.5)	114 (84.6-153.7)	196.9 (156.2-248.1)	77.1 (56.3-105.5)
	Chewing tobacco only	53.6 (41.5-69.3)	135.6 (107.9-170.4)	221.8 (196.3-250.7)	107.7 (87.1-133.2)
	Snuffing tobacco only	74.7 (63.4-88.1)	106.2 (81.9-137.7)	205.5 (180.2-234.4)	82.8 (46.8-146.3)
	Cigarettes and cigars	48.9 (34-70.2)	126.5 (99-161.6)	204.3 (178.6-233.7)	102 (63.4-164)
	Cigarettes and chewing tobacco	No Data			
	Cigarettes and snuffing tobacco	No Data			
NHW	Cigarettes Only	48.3 (47.4-49.2)	113.8 (111.6-116.1)	195.2 (192.6-197.9)	126 (122.2-129.9)
	Pipes only	49.8 (46.8-53)	105.6 (95.2-117.1)	180.4 (167.9-193.8)	99.3 (76.3-129.1)
	Cigars only	48.3 (45.4-51.4)	124.9 (116.3-134.1)	208.2 (198-218.9)	147.3 (134.6-161.3)
	Chewing tobacco only	44.1 (41.9-46.4)	115.9 (109.2-123.1)	190.7 (183.3-198.3)	127.6 (115.3-141.2)
	Snuffing tobacco only	47.4 (42-53.5)	112.7 (101.6-125)	190.5 (177.9-204)	114.6 (98.6-133.3)
	Cigarettes and cigars	48.3 (44-53)	129.6 (101.2-166.1)	206.4 (170.5-249.8)	122.5 (90.3-166.2)
	Cigarettes and chewing tobacco	43.4 (37.2-50.7)	102.2 (82.2-126.9)	183.1 (164.6-203.6)	131.7 (83.8-207)
	Cigarettes and snuffing tobacco	45.6 (38.5-54)	102.5 (92.1-114.1)	182.7 (168.8-197.7)	135.7 (91.1-202.1)
NHB	Cigarettes Only	51.7 (51.3-52.1)	107.3 (106.5-108.1)	186 (185.3-186.8)	100.2 (98.9-101.5)
	Pipes only	No Data			
	Cigars only	52.3 (52.3-52.3)	99.8 (98.5-101)	178.8 (177-180.6)	89.1 (87.3-90.8)
	Chewing tobacco only	53 (50.3-55.8)	133.5 (126-141.4)	211.4 (206.4-216.6)	92.4 (91.7-93.1)
	Snuffing tobacco only	60.1 (60.1-60.1)	125.8 (125.8-125.8)	214.7 (214.7-214.7)	109.6 (109.6-109.6)
	Cigarettes and cigars	Not Enough Data N=1			
	Cigarettes and chewing tobacco	No Data			
MA	Cigarettes Only	46.1 (44.8-47.4)	111.6 (108.1-115.3)	191.7 (187.2-196.4)	136 (127.1-145.5)
	Pipes only	47 (47-47)	149 (149-149)	257 (257-257)	306 (306-306)
	Cigars only	47.5 (36.7-61.3)	116.7 (100.1-135.9)	206.8 (186.4-229.4)	225.5 (101.5-501.3)
	Chewing tobacco only	42.9 (39.3-46.9)	209.4 (140.1-313)	294.5 (210.6-411.7)	179.9 (107.9-299.9)
	Snuffing tobacco only	56.8 (40.1-80.3)	106.6 (87.2-130.4)	195.4 (169-226)	102.5 (61-172.3)
	Cigarettes and cigars	No Data			

	Cigarettes and chewing tobacco	Not Enough Data N=1			
	Cigarettes and snuffing tobacco	Not Enough Data N=1			
OTH	Cigarettes Only	46.6 (44.6-48.6)	112.6 (106.8-118.9)	192.6 (186.2-199.2)	128.2 (118.3-138.9)
	Pipes only	39 (26.8-56.6)	122 (122-122)	177.8 (168.9-187.2)	76.2 (57.3-101.5)
	Cigars only	43.3 (37.8-49.8)	99.6 (87.5-113.4)	179.3 (159-202.2)	127.4 (77.3-210.1)
	Chewing tobacco only	41.9 (32.3-54.2)	105 (70.3-157)	186 (162.4-213)	150.9 (114.7-198.6)
	Snuffing tobacco only	56.6 (50.6-63.3)	92.1 (84.8-100)	161 (147-176.4)	63.3 (60.2-66.6)
	Cigarettes and cigars	57.6 (54-61.3)	90.9 (86.1-95.8)	183.3 (181.6-185.1)	170.2 (147.2-196.6)
	Cigarettes and chewing tobacco	Not Enough Data N=1			
	Cigarettes and snuffing tobacco	No Data			

Table 3 Statistically significant differences by smoking mode* for the geometric mean levels of high density lipoprotein (HDL), low density lipoprotein (LDL), triglyceride in mg/dL with 95% confidence intervals by gender and race/ethnicity for those aged ≥ 20 years. Data from National Health and Nutrition Examination Survey 1999-2012.

	HDL	LDL	Total Cholesterol in mg/dL	Triglyceride in mg/dL
Total	Cig Only >Chw Only (p<0.01), Pip Only>Chw Only (p=0.01), Cgr Only>Chw Only (p=0.01)		Pip Only <Cgr Only (p=0.03)	Pip Only<Cgr Only (p=0.04)
Males	Cig Only<Cig_Cgr (p<0.01), Pip Only>Chw Only (p=0.02), Cgr Only>Chw Only (p=0.04)			Cgr Only>Snf Only (p=0.04)
Females	Cig Only<Cgr Only (p=0.01), Cig Only<Snf Only (p<0.01), Pip Only<Cgr Only (p=0.04), Pip Only<Snf Only (p<0.01), Chw Only<Snf Only (p=0.04)	Cig Only>Pip Only (p=0.03), Pip Only<Chw Only (p=0.01)	Cig Only>Pip Only (p<0.01), Pip Only<Chw Only (p<0.01), Pip Only<Snf Only (p<0.01)	Cig Only >Pip Only (p<0.01), Cig Only >Cgr Only (p=0.01), Pip Only<Chw Only (p<0.01)
NHW	Cig Only>Chw Only (p<0.01), Pip Only>Chw Only (p<0.01), Cgr Only>Chw Only (p=0.03)	Cig Only<Cgr Only (p=0.02), Pip Only<Cgr Only (p=0.01)	Cig Only>Pip Only (p=0.03), Cig Only<Cgr Only (p=0.02), Cig_Chw<Cgr Only (p=0.03), Pip Only<Cgr Only (p<0.01), Cgr Only>Chw Only (p=0.01)	Cig Only<Cgr Only (p<0.01), Pip Only<Cgr Only (p<0.01), Cgr Only>Chw Only (p=0.03), Cgr Only>Snf Only (p=0.01)
NHB	Cig Only<Cig_Cgr (p<0.01), Cig Only<Cgr Only (p<0.01), Cig Only<Snf Only (p<0.01), Chw Only<Snf Only (p<0.01)	Cig Only<Cig_Cgr (p<0.01), Cig Only>Cgr Only (p<0.01), Cig Only<Chw Only (p<0.01), Cig Only<Snf Only (p<0.01), Cig_Cgr>Cgr Only (p<0.01), Cig_Cgr>Cgr Only (p<0.01), Cgr Only<Chw Only (p<0.01), Cgr Only<Snf Only (p<0.01), Chw Only>Snf Only (p=0.04)	Cig Only<Cig_Cgr (p<0.01), Cig Only>Cgr Only (p<0.01), Cig Only<Chw Only (p<0.01), Cig Only<Snf Only (p<0.01), Cig_Cgr>Cgr Only (p<0.01), Cgr Only<Chw Only (p<0.01), Cgr Only<Snf Only (p<0.01)	Cig Only>Cig_Cgr (p<0.01), Cig Only>Cgr Only (p<0.01), Cig Only>Chw Only (p<0.01), Cig Only<Snf Only (p<0.01), Cig_Cgr<Cgr Only (p<0.01), Cgr Only<Chw Only (p<0.01), Cgr Only<Snf Only (p<0.01), Chw Only<Snf Only (p<0.01)
MA	Cig Only>Cig_Snf (p<0.01), Cig_Snf<Cgr Only (p<0.01), Cig_Snf<Chw Only (p<0.01), Cig_Snf<Snf Only (p<0.01),	Cig Only<Cig_Chw (p<0.01), Cig Only>Cig_Snf (p<0.01), Cig Only<Pip Only (p<0.01), Cig Only<Chw Only (p<0.01), Cig_Chw<Chw Only (p=0.03), Pip Only>Cgr Only (p<0.01), Pip Only>Snf Only (p<0.01), Cgr Only<Chw Only (p=0.01), Chw Only>Snf Only (p<0.01)	Cig Only<Pip Only (p<0.01), Cig Only<Chw Only (p=0.01), Cig_Chw>Snf Only (p=0.01), Pip Only>Cgr Only (p<0.01), Pip Only>Snf Only (p<0.01), Chw Only>Snf Only (p=0.03)	Cig Only<Pip Only (p<0.01), Pip Only>Chw Only (p=0.04), Pip Only>Snf Only (p<0.01)
OTH	Cig Only<Cig_Cgr (p<0.01), Cig Only<Snf Only (p<0.01), Cig_Cgr>Cgr	Chw Only>Snf Only (p<0.01), Cig	Cig Only>Cig_Cgr (p=0.01), Cig Only>Pip Only (p=0.01)	Cig Only<Cig_Cgr (p<0.01), Cig Only>Pip Only (p<0.01), Cig

Only (p<0.01), Cgr Only<Snf Only (p<0.01), Chw Only<Snf Only (p=0.04)	Only>Cig_Cgr (p<0.01), Cig Only<Pip Only (p<0.01), Cig Only>Snf Only (p<0.01), Pip Only>Cgr Only (p<0.01), Pip Only>Snf Only (p<0.01)	Only>Snf Only (p<0.01), Cig_Chw>Pip Only (p<0.01), Pip Only<Chw Only (p<0.01), Cgr Only>Snf Only (p=0.01)
*Cig=Cigarettes, Pip=Pipes, Cgr=Cigar, Chw=Tobacco chewers, Snf=Tobacco snuffers		

For the adjusted analysis among smokers, log10 transferred values of HDL, LDL, TC, and TG were used as dependent variables in regression analyses done by SAS Proc SURVEYREG. Categorical independent variables used in regression models were: gender (males, females), race/ethnicity (non-Hispanic white or NHW, non-Hispanic black or NHB, Mexican Americans or MA, and other unclassified race/ethnicities or OTH), physical activity level (vigorous, moderate, none or minimal), smoking type (cigarette only, pipe only, cigar only, tobacco chewer only, tobacco snuffer only, and mixed user) and day of the week for which dietary intake was reported (Sunday, Monday, Tuesday, Wednesday, Thursday, Friday, Saturday). Continuous independent variables used in regression models

were: age, age2, and log10 transformed values of body mass index, NHANES survey year coded as 1 through 7, fasting time in hours, total daily dietary intake of alcohol, caffeine, carbohydrate, total cholesterol, fiber, monounsaturated fatty acids, polyunsaturated fatty acids, saturated fatty acids, total fat, number of days cigarettes, pipes, cigars, and tobacco were chewed during the last five days, and number of cigarettes, pipes, and cigars smoked on the days they were used. Adjusted geometric means (AGM) with 95% confidence intervals are given in **Table 4**. **Table 5** provides data (slopes) on associations that continuous variables like poverty income ratio had with HDL, LDL, TC, and TG.

Table 4 Adjusted geometric means with 95% confidence intervals for fasting high density lipoprotein (HDL), low density lipoprotein (LDL), total cholesterol, and triglyceride in mg/dL by gender, race/ethnicity, smoking mode, dietary intake day, and physical activity levels for those aged ≥ 20 years. Data from National Health and Nutrition Examination Survey 1999-2012.

Variable	Group	HDL	LDL	Total Cholesterol	Triglyceride
Gender	Males (M)	43.3 (38.1-49.2)	127.2 (110.2-146.8)	200.7 (183.2-219.8)	131.7 (103.1-168.1)
	Females (F)	50.4 (44.5-57.1)	125 (108.3-144.3)	203.1 (185.5-222.3)	115.7 (90.9-147.2)
Race/Ethnicity	Non-Hispanic White (NHW)	45.9 (40.4-52.1)	129.5 (112.4-149.2)	205.3 (187.7-224.6)	130.1 (102.5-165.2)
	Non-Hispanic Black (NHB)	50.4 (44.5-57.1)	121.8 (105.7-140.3)	196 (179.2-214.4)	97.7 (77.3-123.4)
	Mexican American (MA)	45.3 (39.9-51.4)	128.4 (110.9-148.5)	204.7 (186.6-224.6)	139.3 (108.6-178.7)
	Others (OTH)	45.4 (39.8-51.8)	124.8 (107.2-145.4)	201.5 (183.1-221.8)	131.1 (101.1-170.1)
Smoking Mode	Cigarettes Only (Cig)	49 (43.4-55.2)	114.5 (100.2-130.7)	195.5 (180.8-211.5)	125.7 (101.9-155.1)
	Pipes only (Pip)	36.8 (29.4-46.2)	204 (147.8-281.5)	242.1 (207-283.2)	117.1 (72.1-190.3)
	Cigars only (Cgr)	48 (42-55)	114.1 (97.4-133.7)	195.9 (177.7-215.9)	133.8 (101-177.3)
	Chewing tobacco only (Chw)	49.7 (42.8-57.7)	120.3 (98-147.6)	197.4 (174.7-223.1)	123.9 (82.6-185.8)
	Snuffing tobacco only (Snf)	49.4 (42.5-57.4)	110.6 (93.7-130.7)	186.7 (166.8-208.8)	101.5 (80.3-128.2)
	Mixed (Mix)	48.9 (43-55.5)	113.3 (97.2-132.2)	198 (179.7-218.2)	142.7 (106.8-190.8)
Dietary Intake Day	Sunday (Sun)	47.2 (41.5-53.6)	120.3 (104.4-138.6)	198.6 (181.1-217.8)	129.1 (98.8-168.6)
	Monday (Mon)	46.4 (40-53.7)	133.8 (113.3-158.1)	209.6 (189-232.4)	130.6 (100.3-170.2)
	Tuesday (Tue)	46 (40.6-52.1)	125.1 (108-144.8)	199.9 (181.8-219.8)	127.1 (99.7-162)
	Wednesday (Wed)	47.2 (41.1-54.2)	132.7 (114.5-153.8)	209.2 (191.3-228.9)	124.5 (96-161.4)
	Thursday (Thr)	47.1 (41.2-53.8)	123.7 (106.6-143.6)	198.4 (180.1-218.5)	116 (90.8-148)
	Friday (Fri)	46.7 (41.2-52.9)	122.4 (106.1-141.2)	197.3 (180.3-215.8)	116.5 (91.8-148)
	Saturday (Sat)	46.5 (41.1-52.7)	125.2 (108.6-144.3)	200.5 (183.2-219.5)	121 (95.8-152.8)
Physical Activity	Vigorous (Vig)	46.4 (40.9-52.7)	130.4 (112.8-150.7)	204.3 (186.3-224)	121.3 (96-153.2)

	Moderate (Mod)	46.2 (40.5-52.7)	126.2 (108.9-146.2)	202.5 (184.4-222.5)	129.4 (100.3-167)
	None or minimal (None)	47.5 (41.9-53.9)	121.8 (105.5-140.7)	198.8 (181.6-217.6)	119.7 (93.7-153.1)
Statistically Significant Differences		M<F (p<0.01), NHW<NHB (p<0.01), NHB>MA (p<0.01), NHB>OTH (p<0.01), Cig>Pip (p<0.01), Pip<Cgr (p=0.01), Pip<Chw (p=0.01), Pip<Snf (p<0.01), Pip<Mix (p<0.01)	NHW>NHB (p<0.01), NHB<MA (p=0.02), Cig<Pip (p<0.01), Pip>Cgr (p<0.01), Pip>Chw (p<0.01), Pip>Snf (p<0.01), Pip>Mix (p<0.01), Sun<Mon (p=0.02), Sun<Wed (p<0.01), Sun<Sat (p=0.04), Mon>Fri (p=0.04), Wed>Fri (p=0.01), Vig>None (p<0.01)	NHW>NHB (p<0.01), NHB<MA (p<0.01), Cig<Pip (p<0.01), Pip>Cgr (p<0.01), Pip>Chw (p<0.01), Pip>Snf (p<0.01), Pip>Mix (p<0.01), Sun<Wed (p=0.01), Mon>Thr (p=0.047), Mon>Fri (p=0.02), Tue<Wed (p=0.03), Wed>Thr (p=0.04), Wed>Fri (p<0.01), Wed>Sat (p=0.03)	M>F (p<0.01), NHW>NHB (p<0.01), NHB<MA (p<0.01), NHB<OTH (p<0.01), Cig>Snf (p=0.01), Cgr>Snf (p=0.01), Snf<Mix (p=0.01), Sun>Thr (p=0.01), Sun>Fri (p=0.01), Tue>Thr (p=0.02), Tue>Fri (p=0.03), Mod>None (p=0.04)

Table 5 Association of dietary and other variables with log10 transformed values of high density lipoprotein (HDL), low density lipoprotein (LDL), total cholesterol and triglyceride when data were analyzed for smokers only. Data from National Health and Nutrition Examination Survey 1999-2012.

	log10 (HDL)		log10 (LDL)		log10 (Total Cholesterol)		log10 (Triglyceride)	
	β	p	β	p	β	p	β	p
Age	-0.00017	0.85	0.01193	<0.01	0.00928	<0.01	0.01238	<0.01
Age2	0.00001	0.39	-0.00012	<0.01	-0.00009	<0.01	-0.00010	<0.01
Survey cycle	0.00708	<0.01	-0.00721	<0.01	-0.00347	0.02	-0.00955	<0.01
Alcohol Intake	0.00069	<0.01	-0.00003	0.69	0.00019	<0.01	0.00003	0.85
Caffeine Intake	0.00000	0.72	0.00003	<0.01	0.00001	0.03	-0.00002	0.21
Carbohydrate Intake	-0.00016	0.00	-0.00004	0.15	-0.00004	0.01	0.00018	<0.01
Total Cholesterol Intake	0.00001	0.48	0.00001	0.35	0.00000	0.66	-0.00002	0.41
Dietary Fiber Intake	0.00120	<0.01	-0.00034	0.43	0.00013	0.62	-0.00011	0.89
Monounsaturated Fatty Acids	-0.00012	0.88	0.00139	0.26	0.00123	0.14	0.00242	0.17
Polyunsaturated Fatty Acids	0.00117	0.13	0.00047	0.70	0.00043	0.57	-0.00050	0.77
Saturated Fatty Acids	0.00135	0.08	0.00072	0.56	0.00090	0.26	0.00160	0.36
Total Fat	-0.00039	0.55	-0.00088	0.42	-0.00084	0.23	-0.00184	0.20
Log10(Body Mass Index)	-0.45514	<0.01	0.16564	<0.01	0.07638	<0.01	0.72353	<0.01
Poverty Income Ratio	0.00402	0.02	-0.00225	0.26	-0.00084	0.49	-0.00617	0.08
Fasting Time in Hours	0.00248	0.02	0.00250	0.08	0.00177	0.05	-0.00252	0.34
Days smoked cigarettes*	-0.00902	<0.01	-0.00040	0.91	-0.00211	0.36	0.00366	0.43
Number of cigarettes smoked**	-0.00002	0.81	0.00018	<0.01	0.00012	0.00	0.00016	0.21
Days smoked pipes*	0.01944	0.11	-0.07657	<0.01	-0.03747	0.00	-0.01637	0.64
Number of pipes smoked**	0.00727	0.10	0.01640	0.24	0.00938	0.23	-0.01347	0.42
Days smoked cigars*	-0.00227	0.62	0.00081	0.90	-0.00214	0.54	-0.00886	0.45
Number of cigars smoked**	-0.00273	0.13	0.00261	0.44	0.00207	0.26	0.00527	0.25
Days chewed tobacco*	-0.01043	0.11	-0.00540	0.58	-0.00510	0.35	-0.00486	0.78
R-Square	26.8%		12.1%		14.8%		17.1%	

*During the last five days

**On the days they were smoked

For the adjusted analysis for smokers vs. nonsmokers, (i) all those who were considered single and dual use smokers were aggregated to form one group called smokers and as such, instead of smoking type as an independent variable, smoking

status was used as one of the independent variable and (ii) dietary variables were not used as independent variables. UGMs and AGMs based the analysis of data for smokers and nonsmokers are given in **Tables 6** and **7**.

Table 6 Unadjusted geometric mean for fasting levels of high density lipoprotein (HDL), low density lipoprotein (LDL), triglyceride in mg/dL with 95% confidence intervals by gender and race/ethnicity for those aged ≥ 20 years by smoking status. Data from National Health and Nutrition Examination Survey 1999-2012.

	HDL in mg/dL			LDL in mg/dL		
	Smokers	Nonsmokers	p	Smokers	Nonsmokers	p
Total	48.2 (47.4-48.9)	52.1 (51.7-52.5)	<0.01	112.9 (111.4-114.4)	112.5 (111.6-113.5)	0.68
Males	46 (45.2-46.7)	46.1 (45.7-46.6)	0.68	112.8 (111-114.6)	113.6 (112.2-115.1)	0.50
Females	51.9 (50.8-52.9)	57.4 (56.9-58)	<0.01	113 (110.5-115.6)	111.7 (110.6-112.8)	0.32
Non-Hispanic Whites	47.9 (47.1-48.8)	52.4 (51.8-52.9)	<0.01	114.2 (112.3-116.1)	112.9 (111.8-114.1)	0.24
Non-Hispanic Blacks	51.9 (50.8-53)	54.5 (53.6-55.3)	<0.01	107.4 (104.6-110.2)	110.9 (109.1-112.7)	0.05
Mexican Americans	46.2 (44.8-47.6)	48.9 (48.3-49.5)	<0.01	111.9 (108.4-115.6)	112.6 (110.6-114.6)	0.75
Others	46.3 (44.6-48.1)	51.3 (50.2-52.4)	<0.01	111.3 (105.8-117)	111.7 (109.4-114)	0.89
	TC in mg/dL			TG in mg/dL		
	Smokers	Nonsmokers	p	Smokers	Nonsmokers	p
Total	193.4 (191.6-195.2)	194.3 (193.1-195.5)	0.39	123.2 (120.2-126.3)	113.5 (111.5-115.5)	<0.01
Males	191.8 (189.7-194)	191.1 (189.4-192.9)	0.61	127 (123.1-130.9)	122.8 (119.7-126)	0.07
Females	195.9 (192.9-199)	196.9 (195.5-198.2)	0.55	117.6 (113.5-121.7)	106.6 (104.5-108.7)	<0.01
Non-Hispanic Whites	195.1 (192.9-197.3)	195.5 (194.1-197)	0.72	126.4 (122.7-130.3)	116.4 (114.1-118.7)	<0.01
Non-Hispanic Blacks	186.1 (183.4-188.9)	189.2 (187.2-191.2)	0.11	98.4 (94.8-102)	87.5 (84.5-90.5)	<0.01
Mexican Americans	192.5 (188-197.2)	192.6 (190.3-195)	0.98	137.5 (128.7-146.9)	123.2 (119-127.4)	<0.01
Others	191.1 (185.1-197.4)	192.4 (189.9-195)	0.69	128.1 (118.5-138.5)	114.5 (109.1-120.1)	0.03

Table 7 Adjusted geometric means with 95% confidence intervals for fasting high density lipoprotein (HDL), low density lipoprotein (LDL), total cholesterol, and triglyceride in mg/dL by gender, race/ethnicity, smoking status, dietary intake day, and physical activity levels for those aged ≥ 20 years. Data from National Health and Nutrition Examination Survey 1999-2012.

Variable	Group	HDL	LDL	Total Cholesterol	Triglyceride
Gender	Males (M)	46.2 (42.9-49.8)	115.5 (106-126)	193.2 (183.5-203.3)	125.3 (109.1-143.8)
	Females (F)	56.6 (52.6-60.9)	114 (104.5-124.4)	199.1 (189.3-209.4)	110.6 (96.4-126.9)
Race/Ethnicity	Non-Hispanic White (NHW)	50.1 (46.5-54)	115.3 (105.6-126)	197.1 (187.1-207.7)	124.8 (108.9-143)
	Non-Hispanic Black (NHB)	55.2 (51.3-59.4)	112.5 (103.2-122.6)	191.7 (182.5-201.4)	90.1 (78.6-103.3)
	Mexican American (MA)	49.8 (46.2-53.6)	116.5 (106.6-127.2)	199.1 (189-209.7)	133.2 (115.9-153)
	Others (OTH)	49.7 (46-53.6)	114.9 (105.3-125.4)	196.6 (186.6-207.2)	128.2 (110.8-148.3)
Smoking Status	Smokers (Smk)	52.2 (48.2-56.4)	114.6 (104.1-126.1)	197.2 (186.1-208.9)	118.6 (102.3-137.5)

	Nonsmokers (Nsmk)	50.1 (46.6-54)	115 (106-124.8)	195 (186.1-204.4)	116.8 (102.3-133.4)
Diet Intake Day	Sunday (Sun)	52.2 (48.5-56.2)	110.9 (102-120.7)	194.1 (185.1-203.6)	118.6 (103.2-136.3)
	Monday (Mon)	49.6 (45.6-53.8)	119.3 (108.5-131.1)	200.2 (189.2-211.8)	124.3 (106.7-144.8)
	Tuesday (Tue)	50.6 (46.9-54.5)	115.6 (105.3-126.8)	197 (186.2-208.4)	123.1 (106.7-142.1)
	Wednesday (Wed)	51.5 (47.6-55.8)	116.7 (106.6-127.8)	198.4 (187.8-209.5)	117.6 (102-135.5)
	Thursday (Thr)	51.6 (47.9-55.6)	112.8 (103.2-123.3)	193.9 (183.9-204.4)	114 (99.2-131.1)
	Friday (Fri)	51.1 (47.5-54.9)	114.5 (105.3-124.6)	194.8 (185.7-204.5)	113.2 (98.5-130.2)
	Saturday (Sat)	51.4 (47.8-55.3)	113.8 (104.5-124)	194.3 (184.8-204.3)	113.5 (99.5-129.5)
Physical Activity	Vigorous (Vig)	51.4 (47.7-55.3)	117.1 (107.2-127.8)	197.5 (187.6-207.9)	114.6 (100.1-131.1)
	Moderate (Mod)	50.3 (46.7-54.3)	115.8 (105.8-126.6)	196.7 (186.5-207.5)	120.1 (103.9-138.8)
	None or minimal (None)	51.7 (48-55.7)	111.6 (102.4-121.5)	194.1 (184.7-203.9)	118.5 (103.2-136)
Statistically Significant Differences		M<F (p<0.01), NHW<NHB (p<0.01), NHB>MA (p<0.01), NHB>OTH (p<0.01), Smk>Nsmk (p=0.02), Sun>Mon (p=0.01), Sun>Tue (p<0.01), Sun>Fri (p<0.01), Sun>Sat (p=0.03), Mon<Thr (p=0.02), Mon<Sat (p=0.04), Vig>Mod (p=0.01), Mod<None (p=0.02)	NHW>NHB (p<0.01), NHB<MA (p<0.01), Sun<Mon (p<0.01), Sun<Tue (p=0.01), Sun<Wed (p<0.01), Sun<Fri (p<0.01), Sun<Sat (p=0.01), Mon>Thr (p<0.01), Mon>Fri (p=0.03), Mon>Sat (p=0.02), Wed>Thr (p=0.03), Wed>Sat (p=0.03), Vig>None (p<0.01), Mod>None (p<0.01)	M<F (p<0.01), NHW>NHB (p<0.01), NHB<MA (p<0.01), NHB<OTH (p<0.01), Sun<Mon (p=0.02), Sun<Wed (p=0.03), Mon>Thr (p=0.02), Mon>Fri (p=0.03), Mon>Sat (p=0.02), Wed>Thr (p=0.02), Wed>Fri (p=0.03), Wed>Sat (p=0.01), Vig>None (p=0.03)	M>F (p<0.01), NHW>NHB (p<0.01), NHW<MA (p<0.01), NHB<MA (p<0.01), NHB<OTH (p<0.01), Sun>Fri (p=0.02), Sun>Sat (p=0.03), Mon>Thr (p=0.01), Mon>Fri (p=0.01), Mon>Sat (p=0.01), Tue>Thr (p<0.01), Tue>Fri (p<0.01), Tue>Sat (p<0.01), Vig<Mod (p=0.04)

Results

While the associations for the log₁₀ transformed values of HDL, LDL, TC, and TG with continuous variables presented as regression slopes (β) are given in **Tables 5** and **8**, percent change in the values of HDL, LDL, TC, and TG for a unit change

in the values of continuous variables, for example, age were computed as $100 \times (10^{\beta} - 1)$ and are presented in selected cases. However, changes in the levels of HDL, LDL, TC, and TG, were computed for a 10% change in the values of body mass index as $100 \times (10^{\beta \times \log_{10}(1.1)} - 1)$.

Table 8 Association of dietary and other variables with log₁₀ transformed values of high density lipoprotein (HDL), low density lipoprotein (LDL), total cholesterol and triglyceride when data were analyzed for both smokers and nonsmokers. Data from National Health and Nutrition Examination Survey 1999-2012.

	log ₁₀ (HDL)		log ₁₀ (LDL)		log ₁₀ (Total Cholesterol)	
	β	p	β	p	β	p
Age	0.00086	0.03	0.00917	<0.01	0.00711	<0.01
Age ²	0.00000	0.55	-0.00008	<0.01	-0.00006	<0.01
Survey cycle	0.00551	<0.01	-0.00814	<0.01	-0.00446	<0.01
Alcohol Intake	0.00061	<0.01	-0.00006	0.29	0.00018	<0.01
Caffeine Intake	0.00001	0.22	0.00002	0.01	0.00000	0.42
Carbohydrate Intake	-0.00013	<0.01	0.00000	0.83	-0.00001	0.40
Total Cholesterol Intake	0.00000	0.88	0.00001	0.45	0.00000	0.76
Dietary Fiber Intake	0.00088	<0.01	-0.00026	0.18	-0.00003	0.80

Monounsaturated Fatty Acids	-0.00025	0.69	0.00045	0.58	0.00023	0.64
Polyunsaturated Fatty Acids	0.00054	0.41	0.00036	0.66	0.00003	0.94
Saturated Fatty Acids	0.00048	0.48	0.00108	0.19	0.00068	0.14
Total Fat	0.00005	0.94	-0.00059	0.43	-0.00029	0.49
log10(Body Mass Index)	-0.44107	<0.01	0.08344	<0.01	0.02263	0.02
Poverty Income Ratio	0.00546	<0.01	-0.00255	0.02	-0.00118	0.09
Fasting Time in Hours	0.00063	0.29	0.00198	0.01	0.00135	0.01
Days smoked cigarettes*	-0.01022	<0.01	-0.00001	1.00	-0.00120	0.40
Number of cigarettes smoked**	-0.00002	0.79	0.00022	<0.01	0.00015	<0.01
Days smoked pipes*	-0.00782	0.33	-0.00862	0.39	-0.01129	0.02
Number of pipes smoked**	0.00575	0.35	0.00916	0.53	0.00568	0.47
Days smoked cigars*	-0.00336	0.33	-0.00046	0.93	-0.00075	0.82
Number of cigars smoked**	-0.00264	0.18	0.00373	0.26	0.00276	0.13
Days chewed tobacco*	-0.00785	<0.01	0.00116	0.80	-0.00134	0.62
R-Square	29.8%		6.8%		9.4%	
*During the last five days; **On the days they were smoked						

Unadjusted geometric means (UGM): Smokers

Dual use vs. single use smokers: In general, dual use smokers were not found to have statistically significantly different levels of any of the four lipid variables than single use smokers. However, among males, cigarette and cigar smokers were found to have higher levels of HDL than cigarette only smokers (50.5 vs. 45.9 mg/dL, **Tables 2 and 3**, $p<0.01$). Among OTH, (i) cigarette and cigar smokers were found to have higher levels of HDL than cigarette only smokers (57.6 vs. 46.6 mg/dL, **Table 2-3**, $p<0.01$) and cigar only smokers (57.6 vs. 43.3 mg/dL, **Table 2**, $p<0.01$), (ii) cigarette and cigar smokers were found to have lower levels of LDL than cigarette only smokers (90.9 vs. 112.6 mg/dL, $p<0.01$), (iii) cigarette and cigar smokers were found to have lower levels of TC than cigarette only smokers (183.3 vs. 192.6 mg/dL, $p<0.01$), and (iv) cigarette and cigar smokers were found to have higher levels of TG than cigarette only smokers (170.2 vs. 128.2 mg/dL, $p<0.01$).

Single use smokers: For the total population, (i) cigarette only, cigar only, and pipe only smokers had higher levels of HDL than those tobacco chewers only (48.4, 49.1, 48.6 vs. 44.5 mg/dL, $p<0.01$, **Tables 2 and 3**), and (ii) pipe only smokers had lower levels of TC (181.2 vs. 197.0 mg/dL, **Table 2**, $p=0.03$) and lower levels of TG (99.6 vs. 129.0 mg/dL, $p=0.04$) than cigar only smokers. Among males, both pipe and cigar smokers had higher levels of HDL than tobacco chewers only (48.3 and 47.2 vs. 44.2 mg/dL, $p<0.01$). Among females, (i) both cigarette only and pipe only smokers had lower levels of HDL than cigar only ($p<=0.04$) and tobacco snuffers only ($p<=0.04$) smokers, (ii) cigarette only and pipe only smokers had lower levels of LDL than cigar only smokers (51.6 and 53.6 vs. 63.0 mg/dL, $p<=0.02$, **Table 3**), (iii) cigarette only smokers had higher levels of TC than pipe only smokers (195.8 vs. 162.9 mg/dL, $p<0.01$,

Tables 2 and 3) and pipe only smokers had lower levels of TC than cigar only smokers (162.9 vs. 196.9 mg/dL, $p<0.01$, **Tables 2 and 3**), and (iv) both cigarette only smokers had higher levels of TG than pipe only smokers (118.9 vs. 55.8 mg/dL, $p<0.01$, **Tables 2 and 3**) and pipe only smokers had lower levels of TG than cigar only smokers (55.8 vs. 77.1 mg/dL, $p<0.01$, **Tables 2 and 3**).

Among NHW, (i) tobacco chewers had lower levels of HDL than cigarette only, pipe only, and cigar only smokers (44.1 vs. 48.3, 49.8, and 48.3 mg/dL, $p<=0.03$, **Tables 2 and 3**), (ii) both cigarette only and pipe only smokers had lower levels of LDL than cigar only smokers (113.8 and 105.6 vs. 124.9 mg/dL, $p<=0.02$, **Tables 2 and 3**), (iii) pipe only smokers had lower levels of TC than both cigarette only and cigar only smokers (180.4 vs. 195.2 and 208.2 mg/dL, $p<=0.03$, **Tables 2 and 3**), and (iv) pipe only smokers had lower levels of TG than both cigarette only and cigar only smokers (99.3 vs. 126.0 and 147.3 mg/dL, $p<0.01$, **Tables 2 and 3**). Among NHB, (i) cigarette only smokers had lower levels of HDL than cigar only as well as tobacco snuffers only (51.7 vs. 52.3 and 60.1 mg/dL, $p<0.01$, **Tables 2 and 3**), (ii) cigarette only smokers had higher levels of LDL than cigar only smokers (107.3 vs. 99.8 mg/dL, $p<0.01$) but lower levels than tobacco chewers and snuffers (107.3 vs. 133.5 and 125.8 mg/dL, $p<0.01$), (iii) cigarette only smokers had higher levels of TC than cigar only smokers (186.0 vs. 178.8 mg/dL, $p<0.01$) but lower levels than tobacco chewers and snuffers (186.0 vs. 211.4 and 214.7 mg/dL, $p<0.01$, **Tables 2 and 3**), and (iv) cigarette only smokers had higher levels of TG than cigar only smokers (100.2 vs. 89.1 mg/dL, $p<0.01$) but lower levels than tobacco snuffers (100.2 vs. 109.6 mg/dL, $p<0.01$). Among MA, (i) cigarette only smokers had lower levels of LDL than pipe only and tobacco chewers only (111.6 vs. 149.0 and 209.4 mg/dL, $p<0.01$, **Tables 2 and 3**), (ii)

cigarette only smokers had lower levels of TC than pipe only and tobacco chewers only (191.7 vs. 257.0 and 294.5 mg/dL, $p<0.01$, **Tables 2 and 3**), (iii) cigarettes only smokers had lower levels of TG than pipe only smokers (136.0 vs. 306.0 mg/dL, $p<0.01$) and pipe only smokers had higher levels of TG than tobacco chewers and snufflers (306.0 vs. 179.9 and 102.5 mg/dL, $p<0.01$, **Tables 2 and 3**).

Adjusted geometric means (AGM): smokers

Females had higher AGM for HDL than males (50.4 vs. 43.3 mg/dL, $p<0.01$, **Table 4**) and lower AGM for TG than males (115.7 vs. 131.7 mg/dL, **Table 4**, $p<0.01$). NHB had higher AGM than NHW and MA (50.4 vs. 45.9 and 45.3 mg/dL, $p<0.01$, **Table 4**) for HDL and NHB had lower AGM than NHW and MA (97.7 vs. 130.1 and 139.3 mg/dL, $p<0.01$, **Table 4**) for TG. In addition, compared to NHW, NHB had lower AGMs for both LDL (121.8 vs. 129.5 mg/dL, $p<0.01$) and TC (196.0 vs. 205.3 mg/dL, $p<0.01$).

Pipes only smokers had lower AGM (36.8 mg/dL) for HDL than cigarette only smokers (49.0 mg/dL, $p<0.01$), cigar only smokers (48.0 mg/dL, $p<0.01$), tobacco chewers only (49.7 mg/dL, $p<0.01$), tobacco snufflers only (49.4 mg/dL, $p<0.01$), as well as mixed tobacco use smokers (48.9 mg/dL, $p=0.01$). Pipes only smokers had higher AGMs for LDL than all other smokers (204.0 mg/dL vs. 110.6 to 120.3 mg/dL, **Table 4**). The same was true for TC (242.1 mg/dL for pipes only smokers, 186.7 to 198.0 mg/dL for other smokers). Pipes only smokers also had the lowest AGMs for TG than all other smokers (117.1 mg/dL vs. 123.9 to 147.0 mg/dL, **Table 4**) except exclusive tobacco snufflers (101.5 mg/dL).

Mixed smokers had higher HDL AGM than pipes only smokers (48.9 vs. 36.8 mg/dL, $p<0.01$, **Table 4**). Mixed smokers had lower LDL AGM than pipes only smokers (113.3 vs. 204.0 mg/dL, $p<0.01$, **Table 4**). Mixed smokers also had lower TC AGM than pipes only smokers (198.0 vs. 242.1 mg/dL, $p<0.01$, **Table 4**).

Daily nutrient intake and lipid levels among smokers

Alcohol intake was positively associated with the levels of HDL ($\beta=0.00069$, $p<0.01$) as well as TC ($\beta=0.00019$, **Table 5**, $p<0.01$). Levels of both TC and LDL increased with increase in caffeine intake ($p<0.01$). Levels of both TC and HDL decreased with increase in carbohydrate intake ($p<0.01$). Dietary fiber intake was positively associated with the levels of HDL ($\beta=0.00120$, $p<0.01$).

Life style variable and lipid levels among smokers

Age and age² was not associated with the levels of HDL but age was positively associated with the levels of LDL, TC, and TG ($p<0.01$, **Table 5**) and age was negatively associated with the values of LDL, TC, and TG ($p<0.01$) meaning increase in the levels of LDL, TC and TG slowed with increase in age.

Log transformed body mass index was negatively associated with the levels of HDL ($\beta=-0.45514$, $p<0.01$) and positively associated with the levels of LDL ($\beta=0.16564$, $p<0.01$), TC ($\beta=0.07638$, $p<0.01$), and TRG ($\beta=0.72353$, $p<0.01$). For a 10% increase in body mass index, HDL levels decreased by 4.4%, and LDL, TC, and TG levels increased by 1.6%, 0.7%, and 7.1% respectively. Poverty income ratio was positively associated with increased levels of HDL ($\beta=0.00402$, $p=0.02$). Fasting time was associated with increased levels of HDL ($\beta=0.00248$, $p=0.02$).

Smoking intensity and lipid levels among smokers

Number of days cigarettes were smoked during the last 5 days was negatively associated with the levels of HDL ($\beta=-0.00902$, $p<0.01$). Numbers of cigarettes smoked on the days they were smoked were positively associated with the levels of LDL ($\beta=0.00018$, $p<0.01$) and TC ($\beta=0.00012$, $p<0.01$). Number of days pipes were smoked during the last 5 days were negatively associated with the levels of LDL ($\beta=-0.07657$, $p<0.01$) and TG ($\beta=-0.03747$, $p<0.01$).

Unadjusted and adjusted lipid levels: Smokers vs. non-smokers

Smokers had lower UGM for HDL (**Table 6**, $p<0.01$) except that HDL UGMs did not differ for male smokers and nonsmokers ($p=0.68$). LDL and TC UGMs did not differ among smokers and nonsmokers (**Table 6**). Smokers had higher UGMs for TG than nonsmokers except that TG UGMs did not differ for male smokers and nonsmokers ($p=0.07$).

Males had lower AGMs for HDL and TC than females (**Table 7**, $p<0.01$) but higher AGMs for TG than females (**Table 7**, $p<0.01$). NHW had lower AGMs for HDL than NHB (**Table 7**, $p<0.01$) but higher AGMs for LDL, TC, and TG than NHB (**Table 7**, $p<0.01$). NHB had higher AGMs for HDL than MA (**Table 7**, $p<0.01$) but lower AGMs for LDL, TC and TG than MA (**Table 7**, $p<0.01$). No differences were observed for HDL, LDL, and TG measures among smokers and nonsmokers but smokers had higher AGM for HDL than nonsmoker ($p=0.02$, 52.2 vs. 50.1 mg/dL, **Table 7**).

Vigorous physical activity was associated with higher AGMs for HDL than when moderate physical activity (**Table 7**, $p<0.01$). Lower AGMs for TG were associated with vigorous physical activity than with moderate and none or minimal physical activity (**Table 7**, $p<0.01$).

Effect of Dietary, Life-Style, and Smoking Intensity Variables: Smokers vs. Non-Smokers

There were almost no differences, as far as statistical significance in concerned, in the impact of dietary, lifestyle, and smoking intensity variables on the levels of HDL, LDL, TC, and TG between the models fitted for various types of smokers

and for smokers vs. nonsmokers. There were only a few exceptions. For the number of days tobacco was chewed during the last five days, for smokers only model, the association with HDL was statistically insignificant ($p=0.10$ but for smoker vs. nonsmoker model, this association was statistically significant ($p<0.01$).

For a 10% increase in body mass index, HDL levels decreased by 4.3%, and LDL, TC, and TG levels increased by 0.8%, 0.2%, and 7.5% respectively.

Time trends

Based on the models fitted for smokers (**Table 5**), for every NHANES cycle, HDL levels increased by 1.6% and the levels of LDL, TC, and TG, decreased by 1.7%, 0.8%, and 2.2% respectively. Based on the models fitted for both smokers and nonsmokers together (**Table 7**), for every NHANES cycle, HDL levels increased by 1.3% and the levels of LDL, TC, and TG, decreased by 1.9%, 1.0%, and 2.3% respectively. Thus, lipid profiles have improved over 1999-2012 for both smokers and non-smokers.

Discussion

Lipid profiles: Smokers vs. non-smokers

When no adjustments were made for factors other than smoking that may affect lipid levels, smokers were found to have higher levels of TG and lower levels of HDL than nonsmokers (**Table 6**) as has been reported in several studies [13-15]. However, when adjustments were made for the effects of gender, race/ethnicity, daily dietary intake of alcohol, caffeine, fatty acids, total fat, body mass index, poverty income ratio, number of days tobacco products were used during the last five days, and number of tobacco products were used on the days they were used, smokers and nonsmokers were not found to differ in their adjusted levels of LDL, TC, and TG (**Table 7**) and smokers had higher adjusted levels of HDL than nonsmokers which is in contradiction to the results reported in quite a few studies as mentioned above. One major difference between this study and other studies reported in this communication is absence of any adjustments made by other studies for the dietary intake of nutrients that may affect lipid and lipoprotein levels. While adjustments for dietary intake of these nutrients may not fully explain the contradictory results between this and other studies, there are other issues that need to be addressed to. Some of the studies mentioned above did and some did not adjust for the frequency and intensity of smoking, this study did. Most of the studies reviewed here were limited to smokers of cigarettes only. In this study, all smokers including single and dual use smokers as well as smokers of smokeless tobacco products were included. It is also essential that the associations that smoking has with body shape and size and the associations that body fat distribution may have with lipid metabolism be understood in order to appreciate the associations that smoking may have with lipid metabolism. Cigarette smoking was reported to be associated with body mass index among

males aged >24 years and smoking was shown to be linked to the development of central adiposity among females and hip circumference, when compared with nonsmokers, was shown to be lower among current female smokers suggesting a loss of muscle mass [16]. Among obese subjects, intra-abdominal visceral fat to subcutaneous fat ratio was reported to be positively correlated [17] with TG and TC ($p<0.001$). The statistical analysis completed for this study did make the adjustments for the associations that smoking may have with body fat distribution and lipid levels by using body mass index along with smoking status as one of the independent variable. NHANES does not provide an index of fat distribution other than body mass index. The only exception has been the availability of fatty and fat free mass but for years 1999-2002 only. Thus, it is suggested that contribution of dietary and fat distribution variables be included in any analysis to study lipid differentials among smokers and nonsmokers.

It should be noted that a reanalysis of the data with cigarette smokers only defined as smokers did not alter the results as far as lipid differentials between smokers and nonsmokers are concerned.

Lipid profile differentials: Different types of smokers

Over 80% of the Americans (95% females) were exclusive cigarette smokers (**Table 1**). About 5% each (11% NHB) were exclusive cigar smokers. About 5% were exclusively tobacco chewers and about 3% were exclusively tobacco snuffers. Less than 1% were pipes only smokers. About 2% were dual use smokers. For this reason, discussion about lipid differentials is primarily limited to exclusive cigarette and cigar smokers and exclusive tobacco chewers and snuffers. Adjusted HDL, TC, and LDL levels did not differ among these four types of exclusive single use users (**Table 4**). Statistically significant pairwise comparisons for HDL, LDL, and TC involved pipes only smokers as one of the member of the pair (**Table 4**). Exclusive cigar smokers had higher levels of TG than exclusive tobacco snuffers (133.8 vs. 101.5 mg/dL, $p<0.01$). Overall, it does not seem what you smoke affects lipid profile. However, in spite of the small to very small samples sizes available for exclusive pipe smokers, exclusive pipe smokers had the lowest adjusted levels of HDL, highest levels of TC and LDL, and almost lowest levels of TG. The reason for this may lie in the type of tobacco leaves and corresponding curing process used to make pipes as compared to the types of tobacco leaves and/or curing processes used to make cigarettes, cigars, chewable and snuffable tobacco. For the overall population, unadjusted levels of HDL were higher for exclusive cigarette and cigar users when compared exclusive tobacco chewers (48.4 and 48.6 vs. 44.5 mg/dL, $p<0.01$, **Tables 2 and 3**) but unadjusted levels of LDL, TC, and TG did not differ among various types of smokers.

Effect of dietary intake

The statistical non-significance (**Tables 5 and 8**) of some of the dietary nutrient intake should be understood with an

adequate knowledge of how adjusted analyses are done in regression models. First, correlations of all of the dietary nutrient intake variables with the remaining independent variables, for example, gender, race/ethnicity etc. are taken into account before “adjusted” correlations with dependent variables are determined and are presented as regression slopes as given in **Tables 5** and **8**. Thus, statistical non-significance of the slopes for dietary nutrient variables does not necessarily mean they have no associations with the lipid levels. This only means they do not have a “totally independent” association with the levels of lipids. Secondly, many of the publications ignore the possibility that nutrient intake may vary from one day to another, for example, there may be more of a tendency to indulge in fatty-fried food when out on dates during weekends. This issue was recognized in this study and to account for this, day of the week for which dietary intake was self-reported was included in the statistical analyses. As can be seen from the results presented in **Tables 4** and **7**, day of the week for which dietary intake was self-reported does affect adjusted levels of lipids, particularly, LDL, TC, and TG.

Effect of fat distribution

The issue of the complex association between fat distribution, smoking, and lipids (and lipoproteins) has been looked among others [18,19]. While body mass index is not the best index of fat distribution but that was the only one available for NHANES data. However, in spite of this, the “independent” association between body mass index and HDL, LDL, TC, and TG was observed as expected (**Tables 5** and **8**). Statistically significant negative associations between body mass index and HDL, and positive associations between body mass index and LDL, TG, and TC were observed. A 10% change in body mass index was associated with a 4.3% decrease in HDL, a 0.8% increase in LDL, a 0.2% increase in TC, and a 7.5% increase in TG for the total population. Thus, the effect of body mass index is observed in the levels of HDL and TG to a larger degree than in the levels of LDL and TC.

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