Association between serum cholesterol and bone mineral density

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Abstract

Background: Hypercholesterolaemia has been associated with low bone mineral density (BMD) in some but not all studies.

Objectives: To examine the influence of age, menopausal status and hormone replacement therapy (HRT) on the relationship between serum cholesterol and BMD in women.

Patients and measurements: 497 female participants (age range 20 - 81) comprising 224 premenopausal and 273 postmenopausal women (156 on HRT and 117 no HRT) underwent measurement of serum cholesterol and BMD.

Results: Serum cholesterol was higher and lumbar BMD was lower in postmenopausal women not taking HRT compared to women those taking HRT. Serum cholesterol was negatively associated with BMD at all measured sites among postmenopausal women not taking HRT in univariate regression analysis (all $p < 0.05$). After adjustment for age, BMI, smoking and alcohol consumption, the relationship between serum cholesterol and BMD remained significant at the lumbar spine and whole body ($p < 0.05$). For subjects in the other groups, no significant association between serum cholesterol and BMD was found. A significant interaction of cholesterol with HRT was detected among post-menopausal women in the regression analyses (all $p < 0.05$).

Conclusion: There is a modest inverse relationship between total serum cholesterol and whole body and lumbar spine BMD in post-menopausal women. HRT use appears to modify this relationship. The mechanisms of this relationship require further study.

Introduction

Hypercholesterolaemia has been associated with low bone mineral density in some [1-3] but not all [4-6] studies. A number of studies have reported a positive relationship between BMD and triglyceride levels[7, 8], while the literature concerning relationships between HDL and LDL cholesterol levels and BMD is conflicting[5, 7, 9-13].
For example, a study of Orozco and colleagues [1] found that early postmenopausal women with an atherogenic lipid profile had lower lumbar and femoral BMD and had an increased risk of osteopaenia compared to those with a normal lipid profile, suggesting that hyperlipidaemia could be associated with osteoporosis. In a longitudinal study in postmenopausal women aged 50–75 years, those with the largest increases in serum cholesterol showed the greatest decreases in spine BMD independently of change in the body mass index [2]. Contradicting these findings, cross-sectional studies by Solomon et al. [5]; Wu and colleagues [6] and a prospective study of Samelson et al. [4] found no relationship between total serum cholesterol levels and BMD, but there were a number of methodological limitations in these latter studies which could affect interpretation.

The existence of a possible link between bone and metabolic pathways has been recognised for some time. Low bone mineral density has been reported to be associated with increased risk of cardiovascular mortality [14, 15] and aortic calcification [3, 16, 17], however, the pathophysiologic mechanisms underlying this association are unknown. A longitudinal study reported that in early postmenopausal women, each decrease of one standard deviation (SD) in distal forearm bone mineral content was associated with a 2.3-fold increased risk for cardiovascular death within the next 17 years. This study also estimated that in 70 year old women, a one SD decrease in their BMD Z-score was associated with a 1.8-fold increase of cardiovascular death [15]. It was suggested that

low bone mass during menopause could be a risk factor for increased cardiovascular mortality in later life [15]. Similarly in the Study of Osteoporotic Fractures (SOF), each one SD decrease of BMD in the proximal radius was associated with a relative risk of 1.7 for stroke death in older postmenopausal women [14, 18]. In this study, the association was not confounded by history of previous stroke, hypertension, postmenopausal use of oestrogen, thiazide use, diabetes mellitus or smoking [14].

The aim of the present study was to examine the relationship between cholesterol levels and bone mineral density at various skeletal sites. Moreover, we sought to specifically examine whether or not such relationships are affected by age, menopausal status or HRT use.

Materials and Methods

Subjects

Study subjects were healthy adult twin pairs aged $\geq$ 18 years recruited as part of the Northern Sydney Twin Study at the Department of Rheumatology of the Royal North Shore Hospital. Subjects taking hormone replacement therapy (HRT) were not excluded, but such use was recorded. Women who have ever taken HRT for more then 6 months within the last 2 years were considered as HRT-users. Participants, taking statins, ezetemibe, gemfibrozil, fenofibrate and bisphosphonates were excluded from the study analyses. The hospital's Human Research Ethics Committee approved the study. Some of these twin data have been previously reported [19-21]. After providing written informed consent, each twin was interviewed separately in accordance with a standard questionnaire to collect demographic, lifestyle and medical history data. Fasting serum

total cholesterol, triglycerides and HDL levels were measured and LDL cholesterol levels were calculated using standard formula: LDL = Total Cholesterol - HDL - (TG / 5) [22].

Bone Mineral Density and Body Composition Measurements.

Baseline characteristics included age, height (m), weight (kg), BMI (weight/height^2, kg/m^2), smoking history, alcohol consumption and menopausal status for women.

Whole body, lumbar spine (L1-L4) and hip sites were scanned by fan-beam dual-energy x-ray absorptiometry (DEXA) using a QDR 4500W (Hologic, Waltham, MA. USA). Bone mineral density (BMD) of the whole body (WBBMD), lumbar spine (LSBMD), total hip (HIPBMD) and femoral neck (FNBMD) were obtained from DEXA scans using standard protocols as previously described [19, 23].

Body composition measures, such as total fat mass (TOT FM) and total lean mass (TOT LM) were obtained directly from whole body DEXA body composition analysis. All scans were analysed by same operator.

Statistical Analysis

A significant interaction of cholesterol with HRT was detected among post-menopausal women in the regression analysis of relationship between cholesterol and BMD at different skeletal sites (all $p < 0.05$). Therefore, the study population was divided into three groups: pre-menopausal women, or post-menopausal women who were either using or not using HRT. T-tests were used for comparing differences in cholesterol and BMD between groups. Pearson correlations were used to examine the relationship between BMD measures and cholesterol. Linear regression analysis was performed to

examine the strength of these relationships after adjusting for potential confounders such as age, BMI, smoking history and alcohol intake. Lack of independence among twin family members was taken into account by excluding one of the members of the MZ twin pairs and using Generalized Estimating Equations (GEE). P values of < 0.05 were considered significant. All statistical analyses were performed using SPSS for Windows 11.5 (SPSS, Chicago, IL) and Stata 8.2.

Results

There were 556 female twin participants (278 pairs, age range 20 to 81 years) in the study. After randomly excluding one member of each MZ twin pair (n = 27), subjects taking cholesterol lowering therapy (28) and bisphosphonates (8), there were 497 women left for the final analyses, comprising 224 premenopausal and 273 postmenopausal women (156 on HRT and 117 no HRT).

The characteristics of the subjects according to these three groups are shown in Table 1. Post-menopausal women, who have never taken HRT, had significantly higher cholesterol levels than post-menopausal women on HRT or pre-menopausal women (6.04 vs. 5.85, and 5.14 mmol/ l, respectively, $p<0.001$). They also had lower BMD measurements at the lumbar spine compare to the other study groups (0.94, 0.96 and 1.05g/cm^2, respectively; $p<0.001$). There was no significant difference in age between postmenopausal women who had never taken or those who had taken HRT (58.5 vs 57.9 years). Fat mass was higher in postmenopausal women not taking HRT than those taking HRT and premenopausal women (26.21, 24.57 and 20.55 kg, respectively; $p<0.001$) and lean mass was higher in premenopausal women ($p<0.001$).

The correlations between cholesterol and BMD at various sites are shown in Table 2. BMD at the lumbar spine and whole body showed statistically significant inverse correlations with total cholesterol level but only in post-menopausal women who had never taken on HRT ($r = -0.236$ and $r= -0.246$, $p < 0.05$, for lumbar spine and whole body, respectively). Figure 1 shows these relationships for the three groups at the lumbar spine site.

Regression analyses for total serum cholesterol, LDL and HDL and bone mineral density at different skeletal sites **were performed**. **The results of univariate analyses presented in Table 3 and multivariate analyses adjusting for age, BMI, smoking history and alcohol intake are presented in Table 4**. Total serum cholesterol was negatively associated with BMD at all sites among postmenopausal women not taking HRT in univariate regression analysis (all $p < 0.05$). **Similar results were found for LDL**. After adjustment for age and BMI, **smoking and alcohol intake** the relationship between serum cholesterol and BMD remained significant at the lumbar spine and whole body ($p = 0.02$ and $p = 0.002$ respectively). Using the total fat mass instead of BMI did not alter the results of the regression. For subjects in the other groups, no significant association between serum cholesterol and BMD was detected.

Discussion

In univariate analyses, higher total cholesterol level was significantly associated with lower BMD at lumbar spine and whole body in postmenopausal women not taking HRT. Moreover, in fully adjusted regression models, the relationship between total cholesterol and BMD remained significant in post-menopausal women who had never taken HRT. This was not seen in premenopausal women or in post-menopausal women

taking HRT. Similar results were reported by the large study of Solomon and colleagues of subjects participating in the NHANES survey [5]. They found that the association between total cholesterol and BMD observed in unadjusted analyses was no longer present in fully adjusted models. However the pooling of data for final analyses in the study of Solomon at al [5] included both genders, a wide age range and pre- and post-menopausal women, regardless of HRT use. Our study suggests HRT use could modify relationship between total cholesterol level and BMD among post-menopausal women, which needs to be accounted for in any statistical analysis.

Previous studies of the relationship between BMD and serum cholesterol have been conflicting. Orozco et al [1] studied 52 obese, early menopausal women (mean age 55 years) with no history of HRT use and found that 29 women with hypercholesterolaemia (defined as > 240mmg/dl) had a higher prevalence of low BMD at the spine (83% vs 55%) and femoral neck 96.5% vs 38%) than 23 women without hypercholesterolaemia.

Samelson et al [4] measured serum cholesterol in 1953-55 in 712 women and 450 men enrolled in the Framingham study. Bone density was not measured until 34 years later (1988-1989). Cross-sectional BMD was similar across quartiles of total cholesterol in both men and women, except for radial shaft BMD in men, which was lower with increasing cholesterol. Mean duration of oestrogen use was two years in women but it was unclear how many women actually used oestrogen and when this was prescribed, although since the mean age at baseline was 41.3 years, presumably some use of the oestrogen was premenopausal or for oral contraceptive purposes. Current use of HRT at the time of BMD measurement was not specified.

We have not found any association between total cholesterol and BMD in post-menopausal women who had a history of HRT use and this may be because HRT use affects the relationship by modifying total cholesterol levels. Most other previous studies of the effect of HRT on plasma lipids have reported that oestrogen use lowers LDL cholesterol and increases HDL cholesterol [24-26], although the effects on total cholesterol have not been reported. Thomsen et al [27] performed a post hoc analysis of 133 postmenopausal women who had participated in a randomised trial of varying doses of oestradiol plus gestodene versus placebo over 3 years. Although BMD increases at the spine and hip correlated with reductions in total cholesterol, endogenous serum cholesterol was high at baseline (6.70 mmol/l) and not associated with BMD of the spine and hip. A positive association has also been reported between the severity of carotid atherosclerosis, serum cholesterol and low total body BMD in older postmenopausal women [3]. In asymptomatic postmenopausal women, those with lumbar osteoporosis have higher coronary calcium scores (indicative of atherosclerosis) than those with normal bone density [16].

Our study is consistent with the study of Tanko et al [2] which found a significant inverse correlation between serum cholesterol at the spine but not the hip in 340 postmenopausal Danish women at baseline. Moreover when followed over 8 years, those women with the largest increases in serum cholesterol showed the greatest decreases in BMD. It is unclear if any women started HRT during the follow-up period of this study. The authors concluded this relationship was due to oestrogen deficiency rather than any direct influence of serum cholesterol on osteoblast function.

However in vitro and in vivo studies indicate that cholesterol and its metabolites can influence the functional activity of osteoblasts [28, 29]. In mice and rabbits fed with atherogenic high-fat diet reduced bone mineralization was observed [30]. In addition,

some [31-37], but not all [38, 39] studies have suggested that statins, widely used as lipid-lowering agents, offer benefits in the preservation of bone mass and the prevention of osteoporotic fractures. Why such an effect would be evident in the spine but not the hip remains unclear, however the relative composition in terms of trabecular versus cortical bone varies at these sites and we and others have previously reported this differential effect on other bone related endpoints. For example we have shown that total body fat mass is related to lumbar spine BMD but not hip BMD in younger subjects [20].

A number of studies have reported a positive relationship between BMD and triglyceride levels[7, 8], while the literature concerning relationships between HDL and LDL cholesterol levels and BMD is conflicting[5, 7, 9-13]. While D'Amelio et al. [10] found an inverse relation, Yamaguchi et al.[13] reported a positive relationship, and Cui et al.[7] and Poli et al. [12] found no relationship. Aside from genetic differences, one possible explanation may be the importance of oestrogen concentration in these groups; most studies have explored relationships in post-menopausal women, but time since menopause varies considerably in different groups, and different studies have taken varying approaches to HRT, some excluding any women on such

Our study has several strengths and limitations. We measured a large number of subjects in a variety of menopausal groupings. However we only measured total cholesterol, not sub-fractions such as LDL or HDL, although this has been reported by others. For example Adami et al [40] studied 236 pre or postmenopausal women attending an osteoporosis clinic as well as 265 men an 481 women from the community and observed a negative relationship between spine and hip BMD and HDL cholesterol in both groups but a positive relationship with LDL cholesterol. Oestrogen use in the last 12 months was an exclusion criterion in that study. Poli et al [12] studied 1303 postmenopausal women attending a menopause clinic, none of whom had taken HRT for

at least 6 months, and found women with increased LDL cholesterol were more likely to have reductions in BMD but no significant relationship with HDL cholesterol. Accordingly the relationship between cholesterol sub-fractions and BMD at different sites clearly needs further study.

In conclusion, we observed a modest inverse relationship between total serum cholesterol and BMD at the spine and not the hip in post menopausal women who had never taken HRT. HRT use appears to act to reverse this relationship between total serum cholesterol and BMD at the spine and needs to be taken into account in future studies. Because oestrogen can have direct effects on bone and cholesterol metabolism, the mechanisms of the relationship requires further evaluation.

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Table 1. Baseline characteristics of study population

Mean (SD)	Women Post-menopausal No HRT (N=117)	Women Post-menopausal on HRT (N=156)	Women Pre-menopausal (N=224)	p*	p**
Age (years)	58.48 (8.72)	57.92 (7.12)	35.81 (9.24)	P <0.001	0.11
Weight (kg)	76.45 (12.27)	75.99 (10.88)	71.56 (11.31)	P <0.001	0.74
Height (m)	1.60 (0.06)	1.62 (0.06)	1.65 (0.06)	P <0.001	0.05
BMI (kg/m^2)	29.83 (5.16)	29.09 (4.47)	26.37 (4.44)	P <0.001	0.20
Total cholesterol (mmol/l)	6.04 (1.01)	5.85 (0.97)	5.14 (0.91)	P <0.001	0.13
LDL (mmol/l)	4.45 (1.06)	4.29 (1.07)	3.61 (0.96)	P <0.001	0.25
Triglycerides (mmol/l)	1.51 (0.88)	1.54 (0.69)	1.21 (0.74)	P <0.001	0.72
HDL (mmol/l)	1.31 (0.51)	1.27 (0.59)	1.33 (0.41)	0.67	0.52
BMD (g/cm^2)					
Lumbar spine (L1-L4) (g/cm^2)	0.944 (0.153)	0.958 (0.144)	1.047 (0.114)	P <0.001	0.45
Total Hip (g/cm^2)	0.902 (0.120)	0.892 (0.131)	0.970 (0.122)	P <0.001	0.50
Femoral Neck (g/cm^2)	0.759 (0.119)	0.750 (0.121)	0.849 (0.116)	P <0.001	0.53
Whole Body (g/cm^2)	1.061 (0.116)	1.080 (0.109)	1.147 (0.095)	P <0.001	0.16
Body Composition					
Total Fat mass (kg)	26.21 (9.42)	24.57 (8.57)	20.55 (9.26)	P <0.001	0.13
Total Lean Mass (kg)	38.77 (4.55)	39.27 (4.67)	41.41 (4.89)	P <0.001	0.38
Smoking					
Never smoked	78	86	136		
Ever Smoked	39	70	88		
Alcohol consumption					
Light (< 5 units per week)	96	114	176		
Moderate (6-15 units per week)	18	38	41		
Heavy (more than 15 units per week)	3	4	7		

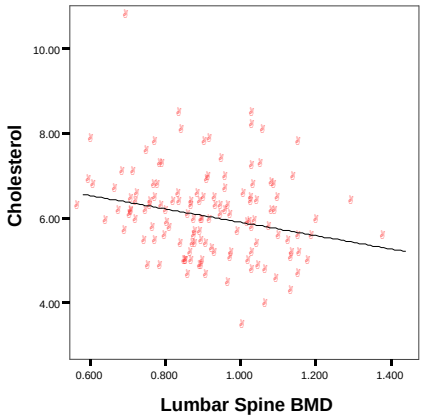
p* - P-values for the results of T-test between post-menopausal women with no HRT history and premenopausal women
p** - P-values for the results of T-test between post-menopausal women with no HRT history and post-menopausal women on HRT

Table 2. Correlations between serum cholesterol and bone mineral density at various skeletal sites

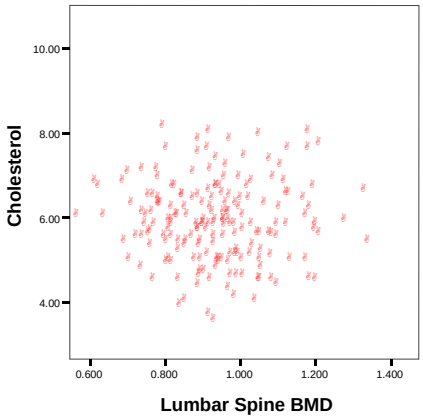
	Post-menopausal women No HRT (n=117)		Post-menopausal women on HRT (n=156)		Pre-menopausal women (n=224)	
	r	P	r	P	r	P
Lumbar spine BMD	-0.20	0.03	-0.002	0.99	0.06	0.34
Total hip BMD	-0.12	0.20	-0.003	0.97	0.005	0.94
Femoral neck BMD	-0.14	0.13	-0.01	0.90	0.02	0.79
Whole body BMD	-0.21	0.02	-0.06	0.47	0.05	0.48

Figure 1. Correlations between total serum cholesterol and Lumbar spine BMD in

Post-menopausal women, no HRT (r= - 0.200; p< 0.05)



Post-menopausal women, on HRT (r= - 0.002; p=0.99)



Pre-menopausal women (r=0.060; p=0.34)

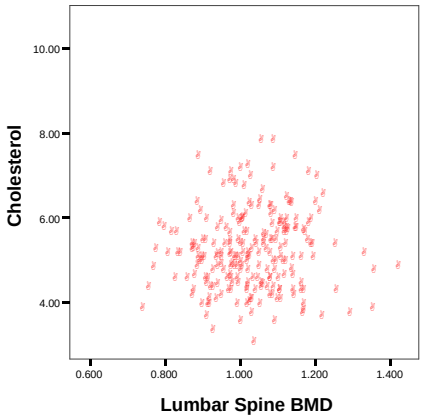


Table 3. Results of the Regression Analysis for serum cholesterol and bone mineral density at various skeletal sites

	Post-Menopausal women No HRT (n=117)		Post-Menopausal women on HRT (n=156)		Pre-Menopausal women (n=224)	
	e^coef (95% CI)	P	e^coef (95% CI)	P	e^coef (95% CI)	P
Lumbar spine BMD						
Unadjusted	0.97 (0.94-0.99)	**<0.01**	1.00 (0.98-1.02)	0.81	1.01 (0.99-1.02)	0.3
Adjusted for age, BMI, smoking and alcohol consumption	0.97 (0.94-1.00)	**0.02**	1.01 (0.99-1.03)	0.21	1.00 (0.99-1.02)	0.61
Total hip BMD						
Unadjusted	0.98 (0.96-1.00)	**0.04**	1.00 (0.99-1.02)	0.91	1.00 (0.98-1.02)	0.81
Adjusted for age, BMI, smoking and alcohol consumption	0.99 (0.97-1.01)	0.19	1.01 (0.99-1.02)	0.47	1.00 (0.98-1.02)	0.98
Femoral Neck BMD						
Unadjusted	0.98 (0.96-0.99)	**<0.01**	1.00 (0.98-1.02)	0.95	1.00 (0.99-1.02)	0.77
Adjusted for age, BMI, smoking and alcohol consumption	0.99 (0.97-1.00)	0.16	1.00 (0.99-1.02)	0.59	1.00 (0.98-1.02)	0.81
Whole body BMD						
Unadjusted	0.97 (0.96-0.99)	**0.001**	1.00 (0.98-1.01)	0.73	1.00 (0.99-1.02)	0.52
Adjusted for age, BMI, smoking and alcohol consumption	0.98 (0.96-1.00)	**0.02**	1.00 (0.99-1.02)	0.63	1.00 (0.99-1.02)	0.7

NEW Table 3. Results of the Crude Regression Analysis for total serum cholesterol, HDL and LDL and bone mineral density at various skeletal sites

	Post-Menopausal women No HRT (n=105)		Post-Menopausal women on HRT (n=144)		Pre-Menopausal women (n=202)	
	B (95% CI)	P	B (95% CI)	P	B (95% CI)	P
Lumbar spine BMD						
Tot cholesterol	-0.036 (-0.06 - -0.012)	**0.004**	0.003 (-0.018 - 0.023)	0.808	0.008 (-0.008 - 0.024)	0.298
LDL	-0.033 (-0.058 - -0.009)	**0.008**	0.009 (-0.013 - 0.030)	0.427	0.015 (-0.007 - 0.031)	0.061
Triglycerides	-0.026 (-0.057 - 0.006)	0.112	0.031 (-0.019 - 0.064)	0.064	0.011 (-0.003 - 0.026)	0.127
HDL	-0.012 (-0.060 - 0.037)	0.639	-0.036 (-0.073 - 0.022)	0.065	-0.056 (-0.092 - -0.017)	**0.005**
Total hip BMD						
Tot cholesterol	-0.018 (-0.036 - -0001)	**0.036**	0.001 (-0.015 - 0.017)	0.912	0.002 (-0.016 - 0.020)	0.810
LDL	-0.018 (-0.036 - -0.00003)	**0.050**	0.012 (-0.005 - 0.028)	0.161	0.010 (-0.007 - 0.026)	0.246
Triglycerides	-0.005 (-0.028 - 0.018)	0.668	0.020 (-0.016 - 0.057)	0.279	0.023 (0.002 - 0.044)	0.031
HDL	-0.011 (-0.055 - 0.032)	0.608	-0.038 (-0.067 - -0.009)	**0.010**	-0.038 (-0.074 - -0.028)	**0.034**
Femoral Neck BMD						
Tot cholesterol	-0.023 (-0.040 - -0.006)	**0.007**	-0.001 (-0.017 - 0.016)	0.950	0.003 (-0.015 - 0.020)	0.766
LDL	-0.021 (-0.039 - -0.003)	**0.026**	0.012 (-0.004 - 0.027)	0.144	0.010 (-0.006 - 0.026)	0.207
Triglycerides	-0.010 (-0.032 - 0.011)	0339	0.019 (-0.015 - 0.053)	0.285	0.014 (-0.003 - 0.032)	0.096
HDL	-0.009 (-0.052 - 0.035)	0.696	-0.045 (-0.072 - -0.018)	**0.001**	-0.046 (-0.081 - -0.011)	**0.009**
Whole body BMD						
Tot cholesterol	-0.028 (-0.045 - -0.012)	**0.001**	-0.003 (-0.018 - 0.013)	0.726	0.004 (-0.009 - 0.017)	0.516
LDL	-0.030 (-0.048 - -0.012)	**0.001**	0.005 (-0.011 - -0.021)	0.549	0.010 (-0.003 - 0.022)	0.142
Triglycerides	-0.033 (-0.054 - -0.012)	**0.002**	0.014 (-0.011 - 0.039)	0.275	0.011 (-0.005 - 0.026)	0.191
HDL	0.025 (-0.018 - 0.067)	0.262	-0.033 (-0.062 - -0.005)	**0.020**	-0.035 (-0.067 - -0.036)	**0.029**

NEW Table 4. Results of the Multiple Regression Analysis for total serum cholesterol, HDL and LDL and bone mineral density at various skeletal sites

	Post-Menopausal women No HRT		Post-Menopausal women on HRT		Pre-Menopausal women	
	B (95% CI)	P	B (95% CI)	P	B (95% CI)	P
Lumbar spine BMD	(n=117)		(n=156)		(n=224)	
Total cholesterol	-0.030 (-0.057 - -0.004)	**0.023**	0.013 (-0.008 - 0.034)	0.214	0.004 (-0.012 - 0.021)	0.610
	(n=105)		(n=144)		(n=202)	
LDL	-0.044 (-0.076 - -0.011)	**0.009**	0.009 (-0.014 - 0.032)	0.452	0.005 (-0.013 - 0.024)	0.574
Triglycerides	-0.007 (-0.046 - 0.032)	0.722	0.009 (-0.029 - 0.047)	0.654	0.005 (-0.025 - 0.015)	0.613
HDL	-0.119 (-0.179 - 0.058)	**<0.001**	-0.018 (-0.061 - 0.024)	0.399	-0.061 (-0.112 - -0.010)	**0.020**
Total hip BMD	(n=117)		(n=156)		(n=224)	
Total cholesterol	-0.012 (-0.031 - 0.006)	0.190	0.006 (-0.010 - 0.021)	0.474	-0.0002 (-0.018 - 0.018)	0.984
	(n=105)		(n=144)		(n=202)	
LDL	-0.018 (-0.044 - 0.008)	0.183	0.011 (-0.007 - 0.030)	0.236	-0.00004 (-0.019 - 0.019)	0.996
Triglycerides	-0.005 (-0.041 - 0.031)	0.794	-0.023 (-0.063 - 0.017)	0.260	0.014 (-0.014 - 0.042)	0.319
HDL	-0.043 (-0.084 - 0.002)	**0.041**	-0.018 (-0.049 - 0.012)	0.241	-0.031 (-0.081 - 0.018)	0.217
Femoral Neck BMD	(n=117)		(n=156)		(n=224)	
Total cholesterol	-0.011 (-0.027 - 0.004)	0.158	0.005 (-0.012 - 0.021)	0.592	0.002 (-0.015 - 0.020)	0.807
	(n=105)		(n=144)		(n=202)	
LDL	-0.015 (-0.040 - 0.010)	0.250	0.008 (-0.010 - 0.025)	0.880	0.002 (-0.015 - 0.020)	0.790
Triglycerides	0.0003 (-0.033 - 0.034)	0.986	-0.017 (-0.054 - 0.020)	0.369	0.004 (-0.017 - 0.026)	0.702
HDL	-0.052 (-0.091 - 0.013)	**0.009**	-0.034 (-0.064 - -0.005)	**0.024**	-0.048 (-0.097 - 0.0004)	0.052
Whole body BMD	(n=117)		(n=156)		(n=224)	
Total cholesterol	-0.022 (-0.040 - -0.004)	**0.018**	0.004 (-0.012 - 0.019)	0.634	0.003 (-0.011 - 0.016)	0.703
	(n=105)		(n=144)		(n=202)	
LDL	-0.022 (-0.046 - 0.001)	0.061	0.003 (-0.013 - 0.020)	0.708	0.003 (-0.011 - 0.018)	0.668
Triglycerides	-0.010 (-0.041 - 0.021)	0.545	-0.007 (-0.037 - 0.022)	0.625	0.003 (-0.015 - -0.002)	0.751
HDL	-0.036 (-0.084 - 0.011)	0.132	-0.030 (-0.060 - 0.001)	0.057	-0.041 (-0.081 - -0.002)	**0.039**

Total cholesterol - Adjusted for age, BMI, smoking and alcohol consumption
LDL - Adjusted for age, BMI, HDL, Triglycerides, smoking and alcohol consumption
HDL - Adjusted for age, BMI, LDL,Triglycerides, smoking and alcohol consumption