Abstract

Introduction: the ABCA1 protein plays a key role in reverse cholesterol transport, promoting its clearance and high-density lipoprotein (HDL) biogenesis. The R1587K (rs2230808) single-nucleotide polymorphism (SNP) in the ABCA1 gene has been associated with dyslipidemia.

Objectives: to investigate the relationship of R1587K genotypes with cardiovascular (CV) risk, metabolic syndrome (MetS), lipid profile, paraoxonase-1 (PON1) activity, and anti-oxLDL titers.

Methods: we performed a cross-sectional study in 57 northern Mexican adults with no reported diseases. The ABCA1 R1587K SNP was detected by real-time polymerase chain reaction (qPCR) using TaqMan allelic discrimination probes. We evaluated the relationship of R1587K with metabolic syndrome and clinical parameters including lipid profile, glucose and insulin, PON1 activity and concentration, anti-oxLDL antibodies, anthropometry and body-composition parameters, and the atherogenic index of plasma calculation.

Results: our results show higher triglyceride levels in the RK + KK carriers as compared to RR carriers (p = 0.031). An association between the RK + KK genotype and the presence of MetS (OR = 4.566, 95% CI = 1.386-14.92, p = 0.010) and a tendency towards high CV risk (OR = 3.317, 95% CI = 0.910-8.611, p = 0.069) was observed in comparison to RR carriers; however, there were no differences in HDL-C levels, PON1 activity and concentration, and anti-oxLDL titers among the R1587K genotypes.

Conclusions: in the northern Mexican population, the ABCA1 gene R1587K SNP is present and the RK + KK genotypes are associated with MetS and increased triglyceride concentrations; therefore, it could be a CV risk biomarker. Nevertheless, there is a need for further confirmation in longitudinal studies.

Keywords:
rs2230808 polymorphism.
Cardiovascular diseases.
Paraoxonase-1.
Anti-oxLDL antibodies.
Hypertriglyceridemia.
R1587K.

Resumen

Introducción: la proteína ABCA1 juega un papel principal en el transporte reverso del colesterol, promoviendo su eliminación y la biogénesis de HDL. El polimorfismo de un solo nucleótido (SNP) R1587K (rs2230808) del gen ABCA1 se ha asociado con dislipidemia.

Objetivo: investigar la relación de los genotipos del SNP R1587K con el riesgo cardiovascular (CV), el síndrome metabólico (SM), el perfil de lípidos, la actividad de paraoxonasa 1 (PON1) y los anticuerpos contra las LDL oxidadas (anti-oxLDL).

Métodos: se realizó un estudio transversal en 57 adultos del norte de México que reportaron no tener enfermedades diagnosticadas. El SNP R1587K del gen ABCA1 se detectó a través de PCR en tiempo real (qPCR) usando sondas TaqMan para discriminación alélica. Para evaluar la asociación del SNP R1587K con el SM y determinados parámetros clínicos se determinaron el perfil de lípidos, los niveles de glucosa e insulina, la actividad y concentración de PON1, los anticuerpos anti-oxLDL, los parámetros antropométricos y de composición corporal, y el cálculo del índice aterogénico en plasma.

Resultados: los resultados mostraron mayores niveles de triglicéridos en los portadores del genotipo RK + KK que en los portadores de RR (p = 0.031). Se observó una asociación entre el genotipo RK + KK y la presencia de SM (OR = 4.566, IC 95% = 1.386-14.92, p = 0.010) y una tendencia hacia un mayor riesgo cardiovascular (OR = 3.317, IC 95% = 0.910-8.611, p = 0.069) al compararlos con los portadores de RR. No se encontraron diferencias en los niveles de HDL-C, la actividad y concentración de PON1 y los anti-oxLDL entre los genotipos R1587K.

Conclusions: el SNP R1587K del gen ABCA1 se encuentra presente en la población del norte de México y el genotipo RK + KK se asocia con el SM y concentraciones elevadas de triglicéridos, por lo que este SNP podría ser un biomarcador de riesgo cardiovascular. Sin embargo, se necesita confirmación a través de estudios longitudinales.
INTRODUCTION

Cardiovascular disease (CVD) is the primary cause of death worldwide. One of the leading disorders that are linked to premature development of CVD is metabolic syndrome (MetS), a condition characterized by multiple alterations including abdominal obesity, hypertriglyceridemia, elevated fasting glucose, hypertension, and low HDL-C levels (1). A key event that precedes CVD is the formation of the atheroma plaque, caused by the unregulated uptake of oxidized low-density lipoproteins (ox-LDLs) by macrophages that progressively turn into foam cells, the main trigger of the atherosclerotic lesion (2) saturable pathway related to the pathway for macrophage uptake of acetylated LDL. Conditioning LDL with cultured aortic smooth muscle cells had a qualitatively similar but smaller effect; conditioning with fibroblasts had no effect. Conditioning very low density lipoproteins or high density lipoproteins with endothelial cells did not affect subsequent metabolism of these lipoproteins by macrophages. Endothelial cell-modified LDL, while degraded more rapidly than control LDL by macrophages, was degraded more slowly by cultured smooth muscle cells and by human skin fibroblasts. Degradation of endothelial cell-modified LDL by macrophages was accompanied by stimulation of cholesterol esterification, inhibition of cholesterol synthesis, and a net increment in total cellular cholesterol content. Thus, a biologically generated modification of LDL is described that markedly alters cholesterol metabolism of macrophages and, consequently, may play a role in foam cell formation during atherogenesis, “arteriosclerosis” (Dallas, Tex.) These oxLDLs elicit the formation of immunogenic epitopes in the LDL molecule, and the subsequent production of anti-oxidized low-density lipoprotein antibodies (anti-oxLDL Abs) (3). However, the physiological role of anti-oxLDL Abs remains controversial since these are present in healthy subjects as well as in different diseases. Therefore, it has been suggested that they may have a pro-atherogenic role, an anti-atherogenic function, or no correlation at all (4-6). The atheroprotective role of HDL particles results from their antioxidative and anti-inflammatory properties, mainly conferred by the paraoxonase-1 (PON1) enzyme, which circulates chemically bound to the apolipoprotein A-I (Apo A1), the largest protein constituent of HDL particles (7). PON1 is a 345 amino-acid glycoprotein, and its serum activity is inversely associated with oxidative stress, as it can hydrolyze lipid peroxides, cholesteryl esters, and oxidized phospholipids, thus preventing the formation of atherosclerotic lesions (8). The circulating levels of HDLs are mainly mediated by reverse cholesterol transport (RCT), of which several pathways have been described—one of them is HDL particles traveling towards peripheral tissues, where their Apo A1 protein region stimulates cholesterol efflux from ATP-binding cassette transporters, ABCA1 and ABCG1, promoting its clearance and/or HDL biogenesis (9). Furthermore, it has been suggested that the PON1 enzyme enhances RCT by facilitating the union of HDL particles to macrophages and the ABCA1 protein (10). The ABCA1 transporter protein is coded for by the ABCA1 gene, located in the long arm of the human chromosome 9 (9q22-31). This protein plays a key role in HDL particle formation and cholesterol efflux from macrophages, thereby precluding the formation of macrophage foam cells (11). Several single-nucleotide polymorphisms (SNPs) in the ABCA1 gene have been reported—R219K (rs2230806), R1587K (rs2230808), and I883M (rs4149313) are the most extensively studied, and have been associated with CV risk and plasma lipid profile (12). Particularly, the R1587K SNP, which is located in exon 35 and induces a change from arginine to lysine in position 1,587 of the ABCA1 protein, has been associated with increased levels of total cholesterol (TC), low-density lipoprotein cholesterol (LDL-C) and TGs, and reduced HDL-C levels (12,13).

Nevertheless, the relationships between R1587K genotypes and lipids levels are inconsistent among all populations, and have not been studied in Mexicans, especially in the northern region population, where dyslipidemias are common, mainly hyperalphalipoproteinemia, hypertriglyceridemia, and hypercholesterolemia (14-middle (India. Therefore, we aimed to evaluate the potential association between the R1587K ABCA1 polymorphism with CV risk and MetS presence, as well as with plasma lipid profile, PON1 activity and concentration, and anti-oxLDL titer in a northern Mexican population.

MATERIAL AND METHODS

SUBJECTS

A cross-sectional study considering 57 apparently healthy adults from Sonora, Mexico, was performed. The subjects disclosed their not having any diagnosed cardiovascular, hepatic, renal, infectious, or thyroid disease, as well as not being under lipid-lowering medication, all these by self report. The study was approved by the Research Center for Food and Development A.C. Ethics Committee Review Board, and was conducted according to the principles of the Declaration of Helsinki. All volunteers were adults and signed an informed consent prior to their inclusion in the study.

BIOCHEMICAL ASSAYS

Blood samples were obtained after overnight fasting and then separated into serum and plasma. Plasma was collected in tubes containing 0.15 g/100 g EDTA and centrifugated at 2400 rpm for 20 min at 4 °C, then placed into vials containing phenyl-methyl-sulfonyl-fluoride (0.015 g/100 g), sodium azide (0.01 g/100 g), and aprotonin (0.01 g/100 g). The sera were collected in tubes containing separator gel, and centrifuged at 3,000 rpm for 20 min at 4 °C.

Plasma total cholesterol (TC), triglycerides (TGs), and glucose were determined using enzymatic colorimetric methods (CHOD-PAP, GPO-PAP and GOD-PAP, respectively), all through commercial reagent sets (Roche Diagnostics, Manheim, Germany). HDL-C was measured in the supernatant after precipitation of the
apo B-containing lipoproteins, and low-density lipoprotein (LDL-C) was determined using the Friedwald equation (15).

Fasting plasma insulin concentration was determined by a sandwich enzyme-linked immunosorbent assay (ELISA) (Grupo Mexlab, Jalisco, Mexico). The homeostasis model of assessment (HOMA) was used to calculate insulin resistance (IR) according to the following equation: IR (HOMA IR) = fasting insulin (µU/mL) fasting glucose (mmol/L) ÷ 22.5 (16). To measure autoantibodies against oxidized LDLs an indirect ELISA oLAB kit (ALPCO, Salem, NH, USA) was used according to the manufacturer’s protocol. The activity of the PON1 enzyme was measured by the arylesterase/paraoxonase assay kit (ZeptoMetrix Corporation, NY, USA). PON1 concentration was quantified through a quantitative sandwich ELISA technique using the Human Serum Paraoxonase-1 (PON1) ELISA kit (Aviscera Bioscience, Inc., CA, USA) according to the manufacturer’s instructions.

DNA EXTRACTION AND GENOTYPING OF THE R1587K POLYMORPHISM IN THE ABCA1 GENE

A sample of peripheral blood was processed for genomic DNA (gDNA) extraction using the phenol-chloroform and proteinase K method (17). DNA quality and integrity were assessed by visualization on 1% agarose gel and SYBR Safe® DNA staining (Life Technologies, USA). The concentration and purity of gDNA were measured on a spectrophotometer (Nanodrop™ 1000, Thermo Fisher Scientific, USA). gDNA samples were stored at -20 °C until the genotyping assay was performed.

The genotypes of the R1587K SNP (rs2230808) were obtained by qPCR (StepOne™, Applied Biosystems, Foster City CA, USA) using TaqMan allelic discrimination probes. Amplification assays were performed according to the standard procedures, using 5 µL of TaqMan Genotyping Mix 2X (Applied Biosystem, Foster City, CA, USA), 0.25 µL of each TaqMan genotyping probe (20x), 20 ng of gDNA, and the corresponding volume of deionized sterile water to complete a total reaction volume of 25 µL. The analysis of PCR data and the genotyping was performed with the StepOne software (version 2.3, Life Technologies Corporation, USA).

CLINICAL DATA

Body composition parameters were measured using a bioelectrical impedance equipment (BIA-101A, RJL Systems, Inc., MI, USA). Body mass index (BMI) was calculated by dividing the weight in kg by the square of height in m. Waist circumference (WC) was measured midway between the lower rib and the iliac crest. Blood pressure was monitored with an automatic blood pressure monitor (HEM-7220, OMRON, USA). Physical activity level (PAL) was evaluated employing the three day record method, and classified into levels according to multiples of basal metabolic rate (18).

METS DIAGNOSIS AND ATHEROGENIC INDEX OF PLASMA (AIP)

The Mets syndrome was carried out as stated by the American Heart Association and the National Heart, Lung, and Blood Institute (19). To evaluate CV risk the AIP was calculated as the logarithmic function of the ratio of plasma TG concentration to HDL-C as Log (TG / HDL-C), and the value of AIP was classified as low CV risk (< 0.11 mmol/L), moderate CV risk (0.11-0.21 mmol/L), and high CV risk (> 0.21 mmol/L) (20).

STATISTICAL ANALYSIS

Data normality was verified by the D’Agostino-Pearson test, and variables with normal distribution were described with their mean ± SD values, whereas the median and 25-75th percentiles were used for variables with non-parametrical distribution. Categorical variables were expressed as percentage and absolute frequency. The relationship between clinical and parametric variables with the R1587K SNP was assessed by differences between groups with Student’s t-test or Mann-Whitney U-test for independent variables, according to the normality distribution. To evaluate the association between ABCA1 R1587K polymorphism genotypes and CV risk, the presence of metabolic syndrome a chi-squared test was performed to estimate the odds ratio (OR) and the 95% CI. Analyses were carried out using the IBM SPSS Statistics 25 (IBM Corporation, USA) package, and the significance level was set at \( p < 0.05 \).

RESULTS

PARTICIPANT CHARACTERISTICS AND DIFFERENCES BY R1587K GENOTYPE

The study population was integrated by 57 participants (29 men and 28 women) with an average age of 38 ± 10 years. Genotypes were distributed as follows: 63.2% had the RR genotype, 26.3% the RK genotype, and 10.5% the KK genotype. Therefore, for statistical purposes we decided to group the RK and KK genotypes (34.1% had RK + KK) for comparison with RR carriers, assuming that the presence of one or two K alleles would modify the risk for the assessed variables.

BMI showed that both study groups were overweight, had an excess of body fat percentage, elevated LDL-C levels, and were also sedentary according to their physical activity level (21). The RR and the RK + KK genotypes carriers had elevated LDL-C and decreased HDL-C levels as compared to the NCEP ATP III guidelines (22). RR carriers showed a moderate CV risk, whereas the RK + KK group had a high CV risk according to the AIP. As seen in table I, triglyceride levels were significantly higher among the RK/KK genotype carriers than among the RR genotype carriers. Also, the RK/KK carriers showed a tendency to greater waist circumference, TC levels, anti-oxLDL Abs, and atherogen-
**Table I. Demographic, body composition, clinical and lifestyle characteristics of the study population, stratified by genotype**

| Parameter                  | Total (n = 57) | RR (n = 36) | RK + KK (n = 21) | p     |
|----------------------------|---------------|-------------|-----------------|-------|
| Age (years)                | 38 ± 10       | 37 ± 11     | 40 ± 10         | 0.233 |
| Sex (male/female) (n)      | 29/28         | 16/20       | 13/8            |       |
| BMI (kg/m²)                | 28.16 ± 4.76  | 27.39 ± 4.08| 29.48 ± 5.60    | 0.111 |
| WC (cm)                    | 91 [84.25-98.55] | 89.9 [82.25-96] | 94.20 [88-104.6] | 0.064 |
| FFM (kg)                   | 53.33 ± 13.10 | 51.17 ± 12.22| 57.03 ± 14.03   | 0.104 |
| Fat mass (kg)              | 25.55 [20.63-30.29] | 24.28 [19.58-28.79] | 26.64 [21.93-32.94] | 0.219 |
| Fat mass (%)               | 31.72 [25.67-41.45] | 31.59 [25.12-41.77] | 33.24 [25.82-41.32] | 0.951 |
| SBP (mmHg)                 | 114.3 ± 15.67 | 111.7 ± 15.97| 118.8 ± 14.41   | 0.100 |
| DBP (mmHg)                 | 76.50 [70.75-84] | 76.25 [70.63-81.75] | 81.50 [71-85.75] | 0.169 |
| Physical activity (multiples of BMR) | 1.65 [1.54-1.77] | 1.64 [1.54-1.73] | 1.68 [1.55-1.80] | 0.405 |
| Smoker (cigarettes/day)    | 0 [0-0]       | 0 [0-0]     | 0 [0-0.85]      | 0.140 |
| Alcohol (mL/day)           | 66.66 [0-253.6] | 44.37 [0-152.1] | 71.42 [0-304.3] | 0.386 |
| Glucose (mg/dL)            | 89.78 ± 10.74 | 88.51 ± 9.99| 91.95 ± 11.87   | 0.246 |
| Insulin (µIU/mL)           | 4.80 [3.95-5.91] | 4.78 [3.81-4.78] | 4.98 [4.22-6.16] | 0.562 |
| HOMA-IR index              | 1.11 [0.84-1.37] | 1.08 [0.82-1.36] | 1.14 [0.91-1.43] | 0.380 |
| TC (mg/dL)                 | 178.23 ± 32.78 | 172.05 ± 32.50 | 188.81 ± 31.19 | 0.061 |
| LDL-C (mg/dL)              | 105.34 ± 27.28 | 103.62 ± 28.49 | 108.29 ± 5.56 | 0.537 |
| HDL-C (mg/dL)              | 39.44 ± 7.35  | 39.56 ± 6.68 | 39.23 ± 8.55   | 0.872 |
| TG (mg/dL)                 | 139.77 [107.70-202.57] | 128.43 [100.27-192.71] | 176.65 [127-227.2] | 0.032 |
| Anti-OxLDL Abs (mU/mL)     | 1,156 [934.20-1,317] | 1,139 [933.60-1,278] | 1,314 [905.60-1,319] | 0.093 |
| PON1 concentration (ng/mL) | 21.16 ± 11.69 | 21.06 ± 11.44| 21.38 ± 12.67   | 0.931 |
| PON1 activity (KU/L)       | 56 [46-64.50]  | 53.63 ± 12.17| 55.95 ± 8.69   | 0.448 |
| AIP (mmol/L)               | 0.22 ± 0.24    | 0.178 ± 0.238| 0.300 ± 0.241  | 0.069 |

Data are given as mean ± standard deviation or median [25-75 interquartile range]. BMI: body mass index; WC: waist circumference; FFM: fat-free mass; SBP: systolic blood pressure; DBP: diastolic blood pressure; BMR: basal metabolic rate; HOMA-IR: homeostatic model assessment-insulin resistance; TC: total cholesterol; LDL-C: low-density lipoprotein cholesterol; HDL-C: high-density lipoprotein cholesterol; TG: triglycerides; anti-OxLDL Abs: anti-oxidized low-density lipoprotein autoantibodies; PON1: paraoxonase-1; AIP: atherogenic index of plasma.

ic index of plasma when compared to RR carriers. However, no significant relationship was detected between ABCA1 R1587K genotypes (RR and RK + KK) with BMI, fat-free mass, fat mass, blood pressure, physical activity, smoking, alcohol consumption, fasting glucose, fasting insulin, HOMA-IR index, LDL-C levels, HDL-C levels, and PON1 concentration and activity (Table I).

**ASSOCIATION OF R1587K GENOTYPES WITH CV RISK AND METS**

The RK + KK genotypes were associated with MetS presence (OR = 4.566, 95% CI = 1.386-14.92, p = 0.010). Also, the RK + KK genotypes showed a tendency to association with higher
CV risk based on the AIP score (OR = 2.800, 95% CI = 0.910-8.611, p = 0.069).

DISCUSSION

The major pathway in HDL particle biogenesis is the RCT, in which the ABCA1 protein plays a pivotal role by stimulating the cholesterol efflux, and precluding the foam cell formation, that induce the atherosclerotic lesion. Several SNPs in the ABCA1 gene have been described. In particular, the R1587K polymorphism has been associated with dyslipidemias and CV risk, but no information exists regarding its relationship with a highly related predecessor of these diseases such as the MetS, and other non-common metabolic and cardiovascular parameters such as lipid-related enzymes and antibodies involved in these pathways. Therefore, we decided to analyze the R1587K SNP in the ABCA1 gene and to evaluate its association with CV risk and MetS presence, as well as its possible role in the lipid profile, PON1 activity and concentration, and anti-oxLDL titers of a northern Mexican population. We found an association between the RK + KK genotype and the presence of MetS, as well as higher TG levels and a tendency towards high CV risk among the RK + KK genotype carriers. However, this polymorphism showed no association with HDL-C levels, PON1, and anti-oxLDL titers.

The frequency of R1587K genotypes in ABCA1 observed in our study was 63.2% for RR and 36.8% for the RK + KK genotypes; to our knowledge, this is the first time that R1587K genotypes have been related to MetS in a Mexican population, having previously been mainly described in Caucasians. These frequencies differ from those in a group of young Greek nurses, showing a reduced frequency of the RR genotype (47.08 %) in comparison to the RR + KK genotypes (52.92%) (26). These differences are likely explained by the genetic heterogeneity extant among populations, which translates into different phenotypes, highlighting the importance of replicating these genetic studies in different populations.

The R1587K SNP, specifically the K allele, in the ABCA1 gene has been previously related with dyslipidemias, specifically with high TC, LDL-C, and TG levels, as well as with lower HDL-C levels in both men and women of the general population or with proven CVD of different age groups (12,13). Although we observed low HDL-C levels among the participants, the concentrations of this lipid fraction showed no relationship with the R1587K SNP; however, TG level turned out to be related with this SNP, being higher among RK + KK carriers. Also, we observed that carriers of the RK + KK genotypes tended to have higher TC and anti-oxLDL Ab levels, abdominal obesity, and high CV risk (as evaluated by the AIP), although not reaching statistical significance. This difference in plasmatic TG levels between the RK + KK genotype carriers as compared to RR genotype carriers is consistent with that reported by Kolovou et al. in Greek women without a history of coronary artery disease (26), and with the tendency described by Ksiazek et al. in children and adolescents undergoing nephrotic syndrome remission (23). Conversely, Jensen et al. reported a lower concentration of TGs in women without CV disease who were carriers of the K allele of this SNP (27).

Even though the direct connection between the ABCA1 protein and TG levels is not fully understood, there is a direct relationship between HDL-C levels and TGs, seen through HDL modeling, where several processes are involved. One of these is mediated by the cholesteryl ester transfer protein (CETP), where an exchange of cholesteryl esters (CE) from HDL to TGs in apoB-containing lipoproteins (LDL/VLDL) occurs (28). This exchange ends in apoB-containing lipoproteins enriched with CEs and drained of TGs, and in HDL particles depleted of CEs.

Table II. Association of ABCA1 R1587K genotypes with CV risk and metabolic syndrome presence

| Total | RR | RK + KK | Odds ratio (95% CI) | $\chi^2$ | $p$ |
|-------|----|---------|-------------------|--------|-----|
|       | n (%) | n (%) | n (%) |                   |        |     |
| AIP   |       |       |       |                   |        |     |
| Low/moderate risk | 28 (49.1) | 21 (58.3) | 7 (33.3) | 1.0 | 3.317 | 0.069 |
| High risk | 29 (50.9) | 15 (41.7) | 14 (66.7) | 2.800 (0.910-8.611) |        |     |
| MetS  |       |       |       |                   |        |     |
| Without MetS | 39 (68.4) | 29 (80.6) | 10 (47.6) | 1.0 | 6.659 | 0.010 |
| MetS  | 18 (31.6) | 7 (19.4) | 11 (52.4) | 4.566 (1.386-14.92) |        |     |

Data are represented in counts (percentages within parentheses). AIP: atherogenic index of plasma; MetS: metabolic syndrome; p-values and ORs with 95% CIs were calculated using Pearson’s chi² test; p < 0.05 was considered significant.
including different genetic variants and proteins involved in lipid metabolism are required. Furthermore, whether the low HDL-C levels observed in our study are due to an increase in TG levels or to the presence of a R1587K SNP remains unknown. Therefore, further and larger-scale studies including different genetic variants and proteins involved in lipid metabolism are required.

Another interesting finding was the association between the RK + KK genotypes and the presence of MetS, in addition to the marginal association detected between the RK + KK genotypes and high CV risk, according to the AIP. This is consistent with the fact that hypertriglyceridermia, alone or in combination with low HDL-C concentrations, has been described as a major factor related to MetS (30). Even though LDL-C has been widely known as one of the major atherogenic lipids, the association between hypertriglyceridermia and risk of CVD has been extensively described (31). Nevertheless, this high risk cannot be completely attributed to the presence of the R1587K SNP, since this population presents with other CV risks including elevated LDL-C and low HDL-C, low physical activity, and altered body composition (elevated body fat percentage, abdominal obesity, and high BMI), all of which contribute to increased CV risk.

A limitation of this study was its relatively small number of participants, so it is necessary to further perform wider studies where these associations with the R1587K genotypes may be corroborated. However, this study adds new information regarding the role of this SNP in the northern Mexican population. Also, we included a novel and common cardiovascular risk biomarker to help elucidate the findings.

In summary, the R1587K SNP of the ABCA1 gene was related to TG level; specifically, RK + KK genotype carriers had higher TG concentrations than RR genotype carriers, while HDL-C levels did not differ between genotypes. Further, an association was found between the RK + KK genotypes and the presence of MetS, as well as a tendency towards high CV risk, indicating that RK + KK carriers are more likely to develop CVD. These findings provide novel information about the presence and implications of the R1587K SNP of the ABCA1 gene in lipid metabolism and CV risk, and could contribute to understand and devise further interventions to prevent the clinical alterations commonly observed in this population.

REFERENCES

1. Okada K, Hibi K, Kohbara M, Kataoka S, Takano K, Akiyama E, et al. Association between blood glucose variability and coronary plaque instability in patients with acute coronary syndromes. Cardiovasc Diabetol Internet 2015 [Accessed on September 19, 2019];14(1). Available at: http://www.cardiab.com/content/14/1/111. DOI: 10.1186/s12933-015-0275-3
2. Henriksen T, Mahoney EM, Steinberg D. Enhanced macrophage degradation of biologically modified low density lipoprotein. Arterioscler Thromb 1983;3(2):149-59. DOI: 10.1161/01.ATV.3.2.149
3. Palinski W, Rosenfeld ME, Yläranta S, Gurner GC, Socher SS, Butter SW, et al. Low density lipoprotein undergoes oxidative modification in vivo. Proc Natl Acad Sci USA 1989;86(4):1372-6. DOI: 10.1073/pnas.86.4.1372
4. Fukushima M, Shoji T, Emoto M, Kawagishi T, Okuno Y, Nishizawa Y. Anti-bodies against oxidized LDL and carotid artery intima-media thickness in a healthy population. Arterioscler Thromb Vasc Biol 2000;20(3):703-7. DOI: 10.1161/01.ATV.20.3.703
5. Tainahones FJ, Gómez-Zumaquero JM, Garrido-Sánchez L, García-Fuentes E, Rojo-Martínez G, Esteva L, et al. Influence of age and sex on levels of anti-oxidized LDL antibodies and anti-LDL immune complexes in the general population. J Lipid Res 2005;46(3):452-7. DOI: 10.1194/jlr.M400290-JLR200
6. Masztalowicz M, Nowacki P, Kotega D, Bajer-Czajkowska A, Drechsler H. Anti-ox-LDL antibodies are clinically insignificant for stroke patients. Neurol Res 2014;36(1):86-91. DOI: 10.1179/174323813X138630268
7. Mackness MI, Hallam SD, Peard T, Warner S, Walker CH. The separation of sheep and human serum «A»-esterase activity into the lipoprotein fraction by ultracentrifugation. Comp Biochem Physiol B 1985;82(4):675-7. DOI: 10.1016/0305-0491(85)90506-1
8. Avram M, Rosenblat M, Biagler CL, Newton RS, Primo-Parsho ML, Da Du BN. Paraoxonase inhibits high-density lipoprotein oxidation and preserves its functions. A possible protective role for paraoxonase. J Clin Invest 1998;101(8):1581-90. DOI: 10.1172/JCI16149
9. Kingwell BA, Chapman MJ, Kontush A, Miller NE. HDL-targeted therapies: progress, failures and future. Nat Rev Drug Discov 2014;13(6):445-64. DOI: 10.1038/nrd4219
10. Juhel S, Berrougui H, Kamchueng S, Omi K, Akhat A, Paraoxonase 1-treated oxLDL promotes cholesterol efflux from macrophages by stimulating the PPARα-LXRα-ABCA1 pathway. FASEB J 2012;6:1599(1):1614-29. DOI: 10.1002/1873-3468.12198
11. Oram JF. HDL Apolipoproteins and ABCA1: Partners in the Removal of Excess Cellular Cholesterol. Arterioscler Thromb Vasc Biol 2003;23(5):720-7. DOI: 10.1161/01.ATV.0000054862.44669.9A
12. Lu Z, Luo Z, Jia A, Yu L, Muhammad I, Zeng W, et al. Associations of the ABCA1 gene polymorphisms with plasma lipid levels: A meta-analysis. Medicine (Baltimore) 2018;97(85):e153251. DOI: 10.1097/MD.0000000000015321
13. Kolovou V, Marvaki A, Boutsikou M, Vasilopoulos G, Degiannis D, Marvaki C, et al. Effect of ATP-binding Cassette Transporter A1 (ABCA1) Gene Polymorphisms on Plasma Lipid Variables and Common Demographic Parameters in Greek Nurses. Open Cardiovasc Med J 2016;10(1):239-34. DOI: 10.2174/187419242016010010233
14. Mendoza-Herrera K, Pedroza-Tobías A, Hernández-Alcarráz C, Ávila-Burgos L, Aguilar-Salinas CA, Barquera S. Attributable Burden and Expenditure of Cardiovascular Diseases and Associated Risk Factors in Mexico and other Selected Mega-Countries. Int J Environ Res Public Health 2019;16;20(20). DOI: 10.3390/ijerph16204041
15. Friedewald WT, Levy RI, Fredrickson DS. Estimation of the concentration of low-density lipoprotein cholesterol in plasma, without use of the preparative ultracentrifuge. Clin Chem 1972;18(6):499-502. DOI: 10.1093/clinchem/18.6.499
16. Matthews DR, Hosker JP, Rudenski AS, Naylor BA, Treacher DF, Turner RC. Homeostasis model assessment: insulin resistance and beta-cell function from fasting plasma glucose and insulin concentrations in man. Diabetologia 1985;28(7):412-9. DOI: 10.1007/BF00280883
17. Sambrook J, Russell DW. Molecular cloning: a laboratory manual. 3rd ed. Cold Spring Harbor, N.Y. Cold Spring Harbor Laboratory Press; 2001. 3 p.
18. Haggerty P, Valencia ME, McNeill G, Gonzales NL, Moya Sf, Pinelli A, et al. Energy expenditure during heavy work and its interaction with body weight. Br J Nutr 1997;77(3):359. DOI: 10.1017/S0007114597000365
19. Grundy SM, Cleeman JC, Daniels SR, Donato KA, Eckel RH, Franklin BA, et al. Diagnosis and Management of the Metabolic Syndrome: An American Heart Association/National Heart, Lung, and Blood Institute Scientific Statement. Circulation 2005;112(17):2735-52. DOI: 10.1161/CIRCULATIONA-HA.105.169404
20. Frohlich J, Dobásová M. Fractional esterification rate of cholesterol and ratio of triglycerides to HDL-cholesterol are powerful predictors of positive findings on coronary angiography. Clin Chem 2003;49(11):1873-80. DOI: 10.1373/clinchem.2003.022558
21. Food and Agriculture Organization/World Health Organization/United Nations University. Human energy requirements. Report of a Joint FAO/WHO/UNU Expert Consultation. Rome; 2001. 96 p.
22. National Cholesterol Education Program (NCEP) Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (Adult Treat-
ment Panel III. Third Report of the National Cholesterol Education Program (NCEP) Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (Adult Treatment Panel III) final report. Circulation 2002;106(25):3143-421. DOI: 10.1161/circ.106.25.3143

23. Książek J, Ciechanowicz A, Wierzbicka A, Syczewska M, Grenda R. Is dyslipidemia sustained during remission of nephrotic syndrome genetically determined? Evaluation of genetic polymorphisms of proteins involved in lipoprotein metabolism in children and adolescents with nephrotic syndrome. Pol Arch Intern Med 2009;119(1-2):11-7. DOI: 10.20452/pamw.592

24. Clee SM, Zwinderman AH, Engert JC, Zwarts KY, Molhuizen HO, Roomp K, et al. Common Genetic Variation in ABCA1 is Associated With Altered Lipoprotein Levels and a Modified Risk for Coronary Artery Disease. Circulation 2001;103(9):1198-205. DOI: 10.1161/01.CIR.103.9.1198

25. Frikke-Schmidt R, Nordestgaard BG, Jensen GB, Steffensen R, Tybjærg-Hansen A. Genetic Variation in ABCA1 Predicts Ischemic Heart Disease in the General Population. Arterioscler Thromb Vasc Biol 2008;28(1):180-6. DOI: 10.1161/ATVBAHA.107.153858

26. Kolovou V, Kolovou G, Marvaki A, Karakosta A, Vasilopoulos G, Kalogiani A, et al. ATP-binding cassette transporter A1 gene polymorphisms and serum lipid levels in young Greek nurses. Lipids Health Dis 2011;10(1):56. DOI: 10.1186/1476-511X-10-56

27. Jensen MK, Pai JK, Mukamal KJ, Overvad K, Rimm EB. Common genetic variation in the ATP-binding cassette transporter A1, plasma lipids, and risk of coronary heart disease. Atherosclerosis 2007;195(1):e172-80. DOI: 10.1016/j.atherosclerosis.2007.01.025

28. Rye K-A, Clay MA, Barter PJ. Remodelling of high density lipoproteins by plasma factors. Atherosclerosis 1999;145(2):227-38. DOI: 10.1016/S0021-9150(99)00150-1

29. Lamarche B, Uffelman KD, Carpenter A, Cohn JS, Steiner G, Barrett PH, et al. Triglyceride enrichment of HDL enhances in vivo metabolic clearance of HDL apo A-I in healthy men. J Clin Invest 1999;103(8):1191-9. DOI: 10.1172/JCI5286

30. Li Z, Deng ML, Tseng C-H, Heber D. Hypertriglyceridaemia is a Practical Biomarker of Metabolic Syndrome in Individuals with Abdominal Obesity. Metab Syndr Relat Disord 2013;11(2):87-91. DOI: 10.1089/met.2012.0000

31. Rosenson RS, Davidson MH, Hirsh BJ, Kathiresan S, Gaudet D. Genetics and Causality of Triglyceride-Rich Lipoproteins in Atherosclerotic Cardiovascular Disease. J Am Coll Cardiol 2014;64(23):2525-40. DOI: 10.1016/j.jacc.2014.09.042