compared to ApoE$^{-/-}$ mice (Figure 3C). Furthermore, type I collagen-positive area was also decreased in ApoE$^{-/-}$IL-17A$^{-/-}$ mice compared to ApoE$^{-/-}$ mice (Supplemental Figure III). These data demonstrate that IL-17A deficiency leads to the formation of atherosclerotic lesion that are composed of abundant macrophage, fewer α-SMA^{+}VSMC at fibrous cap, and lesser type I collagen deposition, suggesting that plaques formed in the absence of IL-17A are vulnerable atherosclerotic plaque.

Increased IFN-γ Production and Decreased IL-5 Production in ApoE$^{-/-}$IL-17A$^{-/-}$ Mice

Next, to assess the immunologic profile of ApoE$^{-/-}$ and ApoE$^{-/-}$IL-17A$^{-/-}$ mice, splenic CD4^{+} T-cells were harvested from ApoE$^{-/-}$ and ApoE$^{-/-}$IL-17A$^{-/-}$ mice before and 8 and 16 weeks after HFD feeding and cultured with PMA and ionomycin in vitro. Culture supernatants were collected and cytokine production was examined by ELISA. High amounts of IL-17A were detected in ApoE$^{-/-}$ mice 8 and 16 weeks after but not before HFD feeding (Figure 4A). Nevertheless, IL-17A was never detected in supernatants derived from ApoE$^{-/-}$IL-17A$^{-/-}$ mice before and after HFD feeding (data not shown). IFN-γ levels were higher in supernatants of the splenic CD4^{+} T-cells from ApoE$^{-/-}$IL-17A$^{-/-}$ mice than those from ApoE$^{-/-}$ mice at 8, but not 16 weeks after HFD feeding (Figure 4B). Supernatants from splenic CD4^{+} T-cells of ApoE$^{-/-}$ mice after HFD feeding for 8 and 16 weeks showed elevated concentrations of IL-5 compared with those before HFD feeding, however, IL-5 production was significantly reduced in ApoE$^{-/-}$IL-17A$^{-/-}$ mice after HFD feeding for 8 and 16 weeks compared with ApoE$^{-/-}$ mice (Figure 4C). Consistently, flow cytometry analysis showed that the number of IFN-γ positive splenic CD4^{+} T-cells was greater in HFD-fed ApoE$^{-/-}$IL-17A$^{-/-}$ mice than that in HFD-fed ApoE$^{-/-}$ mice 8 weeks after HFD feeding (Figure 4D and E). It should be noted that IFN-γ is important in the development of atherosclerosis, whereas IL-5 has an atheroprotective role.[28,29] On the other hand, IL-17A deficiency did not significantly affect IL-4, IL-6, IL-10, and IL-17C production in ApoE$^{-/-}$ mice (Supplemental Figure IV). Therefore, these results suggest that IL-17A deficiency might modulate cytokines' balance in the lymphoid tissue and induces a proatherogenic immunologic response, thereby leading to the augmented atherosclerosis in HFD-fed ApoE$^{-/-}$ IL-17A$^{-/-}$ mice.

Reduced Production of MDA-LDL-Specific IgG$_1$ Antibodies in Sera of ApoE$^{-/-}$IL-17A$^{-/-}$ Mice

We first assessed the levels of Ig subclasses in serum of mice before and after HFD feeding for 8 weeks. The rationale for doing this experiment is follows: a signature Th1 cytokine, IFN-γ promotes the development of arteriosclerosis, and Th1 cells favor IgG$_{2a}$ production, whereas Th2 cells induce IgG$_1$ synthesis.[30] There was no significant difference in the production of total IgG, IgG$_1$, IgG$_{2a}$, or IgM between HFD-fed ApoE$^{-/-}$ and ApoE$^{-/-}$IL-17A$^{-/-}$ mice (data not shown). We next assessed levels of MDA-LDL–specific antibodies, as they are likely to be some of the most prevalent presumptive autoantigens present in atherogenic mice model.[31] There is no

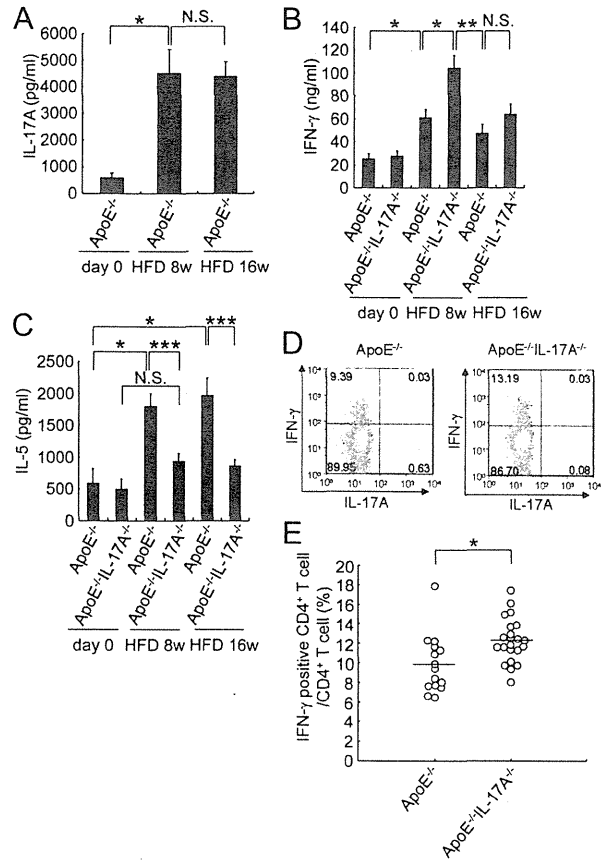

Figure 4. Interferon (IFN)-γ production was increased and interleukin (IL)-5 production was decreased in apolipoprotein E (ApoE) double-deficient (ApoE$^{-/-}$)IL-17A$^{-/-}$ mice. Quantitative analysis of IL-17A (**A**), IFN-γ (**B**), and IL-5 (**C**) production in the supernatants of splenic CD4-positive T-cells from ApoE$^{-/-}$ and ApoE$^{-/-}$IL-17A$^{-/-}$ mice before (n=4–6 per each group) and after 8 (n=17–22 per each group) and 16 (n=17–27 per each group) weeks of high-fat diet (HFD) feeding. Splenic CD4^{+} T-cells were cultured in vitro with PMA and ionomycin; culture supernatants were examined by ELISA. **D**, Representative examples of intracellular IFN-γ and IL-17A staining of isolated splenocytes from ApoE$^{-/-}$ and ApoE$^{-/-}$IL-17A$^{-/-}$ mice fed the HFD for 8 weeks. Plots are gated on CD3^{+} and CD4^{+} cells. E, Ratio of the number of IFN-γ-positive cells to the total number of splenic CD3^{+} and CD4^{+} T-cells. Horizontal bars indicate mean values. ApoE$^{-/-}$ (n=14), ApoE$^{-/-}$IL-17A$^{-/-}$ (n=22). *p < 0.05. **p < 0.005. ***p < 0.0005. N.S., not significantly different.

significant difference in any subclasses of anti-MDA–LDL antibodies between ApoE$^{-/-}$ and ApoE$^{-/-}$IL-17A$^{-/-}$ mice before HFD feeding (Figure 5 and Supplementary Figure V). ApoE$^{-/-}$IL-17A$^{-/-}$ mice produced significantly lesser amounts of IgG$_1$ class of anti-MDA–LDL antibody compared to ApoE$^{-/-}$mice after HFD feeding for 8 weeks but not for 16 weeks (Figure 5). However, IgG$_{2a}$ class of anti-MDA–LDL antibody did not differ between 2 groups (Supplementary Figure V), indicating that the absence of IL-17A does not simply affect the balance between Th1 and Th2.

IL-17A Treatment Led to Attenuated Atherosclerosis Plaque Formation in ApoE$^{-/-}$ and ApoE$^{-/-}$IL-17A$^{-/-}$ Mice

The results above suggest that IL-17A plays a protective role against the development of atherosclerosis. Therefore,

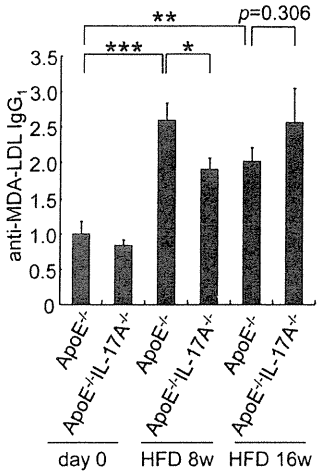

Figure 5. Production of MDA-LDL–specific IgG_1 antibodies was suppressed in the sera of apolipoprotein E (ApoE) double-deficient ($ApoE^{-/-}$)interleukin (IL)-$17A^{-/-}$ mice. We examined the humoral response to IL-17A deficiency by quantifying MDA-LDL–specific antibody titers in sera. Quantitative analysis of the levels of MDA-LDL–specific antibodies, IgG_1 in $ApoE^{-/-}$ (n=21) and $ApoE^{-/-}IL\text{-}17A^{-/-}$ (n=35) mice before and after 8 or 16 weeks of high-fat diet (HFD) feeding. $^*p < 0.05$. $^{**}p < 0.005$. $^{***}p < 0.0005$.

we studied whether exogenous IL-17A prevents atherosclerotic plaque formation. Administration of IL-17A twice a week during HFD feeding led to a significant elevation of circulating IL-17A levels (data not shown). We analyzed $ApoE^{-/-}$ mice fed with the HFD for 12 weeks starting at age 8 weeks, treated with either IL-17A or mouse albumin/PBS during HFD feeding twice a week. Indeed, treatment with IL-17A resulted in attenuated atherosclerosis plaque formation in HFD-fed $ApoE^{-/-}$ mice (Figure 6A). We also tested whether exogenous IL-17A, starting at age 5 weeks, reduces the development of atherosclerosis in $ApoE^{-/-}IL\text{-}17A^{-/-}$ mice fed with the HFD for 10 weeks and found that IL-17A significantly reduced atherosclerotic plaque area in $ApoE^{-/-}IL\text{-}17A^{-/-}$ mice (Figure 6B). These results suggest that IL-17A plays a protective role against the development of atherosclerosis in this setting and that manipulation of IL-17A may be a therapeutic approach for the progression of atherosclerosis.

Discussion

Atherosclerosis is characterized as a chronic inflammatory process of vessel walls and $CD4^+$ T-cells are predominant in both human and murine atherosclerotic lesions.[9,32] Depletion of $CD4^+$ T or CD4 deficiency reduces fatty streak development in C57BL/6 mice fed with an atherogenic diet.[33] It has been shown that Th1 cell-derived IFN-γ or IL-12 is proatherogenic.[10,11,34] However, IL-17A–producing Th17 cells are also involved in the development of atherosclerosis; IL-17A is increased in the plasma of unstable angina and acute myocardial infarction patients[35] and IL-17A/IFN-γ dual-producing T-cells are present within coronary plaques.[12] In addition, IL-17A induces MMP-9 production from macrophages, which is related to vulnerable plaque.[36,37] However, recently conflicting roles of IL-17A on arteriosclerosis have been reported.

Contrary to our results, numbers of papers independently supported the notion that IL-17A is proatherogenic. First, transfer of IL-17 signaling deficient bone marrow (BM) cells into atherosclerosis prone mice led to the significant reduction of atherosclerosis at aortic root, indicating that IL-17-signaling in BM-derived cells promotes the process of ath-

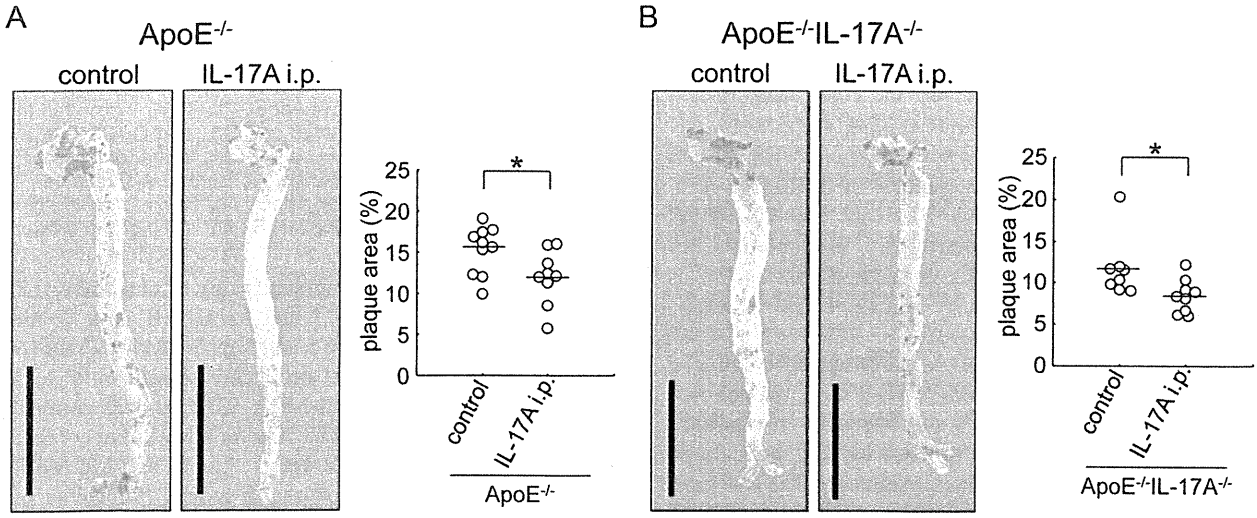

Figure 6. Interleukin (IL)-17A treatment attenuated atherosclerosis plaque formation in apolipoprotein E (ApoE) double-deficient $ApoE^{-/-}$ and $ApoE^{-/-}IL\text{-}17A^{-/-}$ mice. **A**, We determined whether exogenous IL-17A prevents atherosclerotic plaque formation. We treated $ApoE^{-/-}$ mice with recombinant mouse IL-17A (2 μg/mouse) diluted in PBS containing 0.05% mouse albumin or PBS containing 0.05% mouse albumin (albumin/PBS) twice a week during 12 weeks of high-fat diet (HFD) feeding. Representative macroscopic images of oil red O-stained aortae in $ApoE^{-/-}$ mice treated with (n=8) or without (n=10) IL-17A and quantitative analysis of oil red O-stained aortae. **B**, Additionally, we treated $ApoE^{-/-}IL\text{-}17A^{-/-}$ mice with recombinant mouse IL-17A (2 μg/mouse) or albumin/PBS twice a week during 10 weeks of HFD feeding. Representative macroscopic images of oil red O-stained aortae in $ApoE^{-/-}$ mice treated with (n=9) or without (n=7) IL-17A and quantitative analysis of oil red O-stained aortae. Scale bars indicate 10 mm. Horizontal bars indicate mean values. $^*P<0.05$.

erosclerosis.[13] Interestingly, plaque stability was unchanged. In their system, IL-17 signaling is lacking only in BM cells, whereas in our system IL-17 signaling is lacking in both BM cells and VSMC. It is possible that VSMC in their system was able to respond to IL-17 and thus these cells might produce MMPs, which might explain the unchanged plaque stability between mice that receive IL-17R$^{-/-}$BM and IL-17R^{+}BM cells. In our model, plaque became unstable in ApoE$^{-/-}$IL-17A$^{-/-}$ mice, indicating that the stimulation of VSMC by IL-17A may play a critical role in plaque stability. Second, ApoE$^{-/-}$ mice, starting at age 8 weeks were fed with a normal chow diet for 12 weeks with anti-IL–17A antibody once a week and were analyzed at the age of 20 weeks.[14] Inhibition of IL-17A reduced atherosclerotic lesion area and induced stability of plaque. The basis for the discrepancy between their and our data are currently not known; however, blockade of IL-17A function is not complete in previous study,[14] whereas in our study IL-17A is completely absent due to deletion of IL-17A gene. This may be reflected by the unchanged proportion of CD4^{+}IFN-γ^{+} Th1 cells against CD3^{+} T-cells between anti-IL–17A antibody treated and nontreated groups in previous report. In our case, we found the significant increase of CD4^{+}IFN-γ^{+} Th1 cells and IFN-γ production in ApoE$^{-/-}$IL-17A$^{-/-}$ mice 8 weeks after HFD feeding (Figure 4B, 4D, and 4E), consistent with the idea that IFN-γ is important in atherogenesis.[38] Third, ApoE$^{-/-}$mice fed with HFD for 15 weeks exhibited increased Th17 cells when examined at age of 21 weeks.[15] The adenovirus-mediated blocking of IL-17 receptor A-signaling reduced atherosclerosis and accumulation of macrophages at plaque. Importantly, IFN-γ levels did not differ between control and IL-17 receptor A treated ApoE$^{-/-}$ mice[15] and it is possible that the adenovirus-mediated blocking of IL-17 receptor A-signaling may not be complete and this may explain the discrepancy between our and their results. In another report, ApoE$^{-/-}$ mice were fed with HFD for 10 weeks, starting at age 8 weeks and these mice were further treated with anti-IL–17A antibody for 4 weeks or recombinant IL-17A for 5 weeks, which resulted in the attenuation or exacerbation of atherosclerosis, respectively.[16] Exogenous IL-17A also promoted atherosclerotic lesions with instability of plaque.[16] Effects of IL-17A on atherosclerosis development was entirely opposite to what we found in this study. One possible explanation for this discrepancy may be the age of mice used and the timing of treatment intervention. It has been known that atherosclerosis process starts in childhood.[39] Thus under our experimental model, effect of IL-17A was tested during early stage of atherosclerosis development. While they examined the effect of IL-17 in late phase of atherosclerosis development.

On the other hand, similar to what we found, there are reports that IL-17A is a protective against atherosclerosis. First, Taleb et al demonstrated that when SOCS3-deficient T-cells with increased IL-17A production and reduced IFN-γ production were given to HFD-fed LDLR$^{-/-}$ mice, the development of atherosclerotic plaque areas was significantly limited.[19] This cytokine profile reminded our finding that level of IL-17A and IFN-γ was inversely related in CD4^{+} T-cells of HFD-fed ApoE$^{-/-}$ mice. Importantly, normal mouse aorta, VSMC of LDLR$^{-/-}$ that had received SOCS3-deficient T-cells and VSMC in human arteriosclerosis expressed IL-17A. Along with progression of atherosclerosis, the IL-17A staining seems to be rapidly lost in VSMC, suggesting that vascular expression of IL-17A is associated with plaque stability. Similarly, HFD-fed ApoE$^{-/-}$IL-17A$^{-/-}$ mice, which completely lacks IL-17A in VSMC led to the formation of unstable plaque in our model (Figure 3). Therefore, IL-17A produced by not only T-cells but also vascular walls should be taken into consideration for the physiological and pathological role of IL-17A during development of arteriosclerosis. Second, CD20 antibody-mediated B-cell depletion in ApoE$^{-/-}$ and LDLR$^{-/-}$ mice led to skewing of T-cell differentiation, more specifically toward Th17 cell differentiation, thus resulting in higher IL-17A and lesser IFN-γ production and attenuated atherosclerosis.[20] Atherosclerotic lesions in IFN-γ– or IFN-γR–deficient mice were reduced, whereas IFN-γ-treated ApoE$^{-/-}$ mice showed enhanced atherosclerotic plaque areas,[11,40,41] suggesting that IFN-γ has proatherogenic functions. In addition, IFN-γ produced vulnerable atherosclerotic plaque by inhibiting VSMC proliferation or collagen production.[41,42] Therefore, it is reasonable to speculate that IL-17A deficiency led to the increased IFN-γ production in splenic CD4^{+} T-cells, thereby facilitating the atherosclerotic plaque formation in HFD-fed ApoE$^{-/-}$ mice. In fact, we observed that MOMA-2^{+} macrophages were increased and α-SMA^{+}VSMC were decreased in ApoE$^{-/-}$IL-17A$^{-/-}$ mice compared to ApoE$^{-/-}$ mice, supporting the idea that the increased production of IFN-γ is responsible for exacerbation of atherosclerosis and instability of atherosclerotic plaque in ApoE$^{-/-}$IL-17A$^{-/-}$ mice.

In addition, we also found that IL-5 and anti-MDA–LDL IgG_1 production was decreased in HFD-fed ApoE$^{-/-}$IL-17A$^{-/-}$ mice. Of note, anti-MDA–LDL antibody was reported to be antiatherogenic in some studies.[43] In another report, IL-33 treatment reduced atherosclerotic plaque formation in ApoE$^{-/-}$ mice.[44] In that study, IL-33 promoted the production of IL-5 and antiox-LDL antibody and diminishing IFN-γ production[44] and played an antiatherogenic role via production of IL-5. Therefore, it is possible that the impaired production of IL-5 led to the decreased anti-MDA–LDL IgG_1 production, thus accelerating atherosclerosis in HFD-fed ApoE$^{-/-}$IL-17A$^{-/-}$ mice.[45,46] However, production of IL-4 by splenic CD4^{+} T-cells did not differ significantly between ApoE$^{-/-}$ and ApoE$^{-/-}$IL-17A$^{-/-}$ mice after HFD feeding in our model. Thus, our data indicate that the presence or absence of IL-17A does not simply favor the generation of Th2 cytokines in general.

During preparation of this manuscript, an important report using ApoE$^{-/-}$IL-17A$^{-/-}$ mice, which we also used in our study, was published.[47] They found that IL-17A did not influence atherosclerotic plaque development, however it did influence some aspects of vascular inflammation and thus plaque stability.[47] They found no change in the extracellular matrix components in vascular walls by conventional Russell-Movat–pentachrome staining between ApoE$^{-/-}$IL-17A$^{-/-}$ and ApoE$^{-/-}$ after HFD feeding.[47] However, we found that type I collagen deposition (Supplemental Figure III) and α-SMA^{+}VSMC (Figure 3C) were decreased in plaque

in the absence of IL-17A by using specific antibodies. They also found that ApoE$^{-/-}$IL-17A$^{-/-}$ mice were resistant to HFD-induced weight gain.[47] We found that both ApoE$^{-/-}$IL-17A$^{-/-}$ and ApoE$^{-/-}$ mice gained weight similarly after HFD feeding. Consistent with our data, Gao et al reported that ApoE$^{-/-}$ mice gained significant weight after HFD feeding regardless of neutralization of IL-17A or addition of recombinant IL-17A.[16] The reason for this discrepancy between our data and their data[47] using the same ApoE$^{-/-}$IL-17A$^{-/-}$ mice is currently not known, however, we started feeding mice with HFD at earlier time compared to their treatment protocol.[47] Our data in which clear upregulation of IFN-γ, reduction of IL-5, and reduction of anti-MDA–LDL IgG_1 increased accumulation of macrophage and reduced appearance of α-SMA$^+$VSMC at fibrous cap of plaque are evident at HFD feeding for 8 weeks, indicating the possibility that IL-17A and thus IFN-γ and IL-5 may play a role in early stage of atherosclerosis formation and once atherosclerosis was established, its progression or deterioration is not critically affected by IFN-γ.

In summary, IL-17A deficiency led to the formation of the unstable atherosclerotic plaque in HFD-fed ApoE$^{-/-}$ mice. These outcomes might be attributable to increased IFN-γ and decreased IL-5 productions in splenocytes and decreased IgG_1 antibody against MDA-LDL in sera. Moreover, treatment with IL-17A attenuated atherosclerosis progression in HFD-fed ApoE$^{-/-}$ mice. However, it should be reminded that the role of IL-17A in the development and nature (instability) of arteriosclerosis may be considerably influenced by multiple factors, such as cytokine profile (IFN-γ and IL-5), level of IL-17A (partial inhibition versus complete absence), IL-17A–signaling in VSMC, and stage of atherosclerosis development. Therefore, the role of IL-17A on atherosclerosis development needs further investigation.

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Disclosures

None.

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Supplemental Material

Interleukin-17A deficiency accelerates unstable atherosclerotic plaque formation in apolipoprotein E-deficient mice

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Expanded Materials and Methods

Mice

IL-17A-deficient mice used in this study were created as described previously[1]. C57BL/6 ApoE-deficient male mice ($ApoE^{-/-}$) (backcrossed 10 times; The Jackson Laboratory, Bar Harbor, ME) were bred with IL-17A-deficient ($IL\text{-}17A^{-/-}$) female mice on a C57BL/6 background (backcrossed 10 times). Heterozygous F1 progeny were

interbred to yield F2 genotypes. IL-17A wild-type (WT) and IL-17A-deficient mice among ApoE-deficient mice were designated as $ApoE^{-/-}$ and $ApoE^{-/-}IL\text{-}17A^{-/-}$, respectively. These mice were intercrossed to yield $ApoE^{-/-}$ and $ApoE^{-/-}IL\text{-}17A^{-/-}$, which served as subjects in this experiment on a C57BL/6 background. ApoE deficiency in these mice was defined by a phenotype of elevated serum cholesterol in blood as described previously[2]. IL-17A genotyping was performed by polymerase chain reaction analysis of tail DNA as described previously[1]. All animal protocols were approved by the committee on animal experimentation of Hokkaido University.

Diet and experimental design in the high-fat diet model

Male $ApoE^{-/-}$ and $ApoE^{-/-}IL\text{-}17A^{-/-}$ mice whose body weights were between 16.0 and 22.0 g were weaned at 6-8 weeks of age and fed an atherogenic high-fat diet (HFD) (0.15% cholesterol and 21% milk fat, 57BD; TestDiet, Richmond, USA) or normal chow diet ad libitum. Eight or 16 weeks after HFD or normal chow diet feeding, the mice were killed, and atherosclerosis was determined using an en face method[2]. The heart and aorta from the aortic root to the iliac branch were removed; aortae were fixed in 10% phosphate-buffered formalin for histopathology. Aortic roots were embedded in OCT compound (Sakura Finetek) and stored at -80°C. The blocks were sectioned at 10

or 6 μm thickness and fixed for 10 min in 10% phosphate-buffered formalin at R.T. or acetone at -20°C.

Analysis of atherosclerotic lesions

The degree of atherosclerosis was determined by quantifying oil red O staining in en face lesions in pinned-out aortae [2, 3]. Briefly, the mice were perfused with PBS followed by 10% phosphate-buffered formalin. The aorta was opened longitudinally from the aortic root to the iliac branch and from the iliac bifurcation to a point equidistant from the aortic valve. The brachiocephalic artery was removed, pinned out flat on a black wax surface, and stained with oil red O. The aortas were then photographed, and the total surface and entire lesion areas were measured by planimetry.

Histopathology

Serial 6-μm sections were taken from the aortic valve or abdominal aorta area. Sections were fixed for 10 min in acetone at -20°C and used for immunohistochemistry. In another experiment, sections (10 μm thick) were fixed for 10 min in 10% phosphate-buffered formalin and oil red O stain or hematoxylin and eosin (H&E) to determine the plaque area.

Immunohistochemistry

A monoclonal antibody against α-smooth muscle actin (α-SMA), clone 1A4, was purchased from Sigma-aldrich. A monoclonal antibody against macrophages, MOMA-2, was purchased from Serotec. A rabbit polyclonal antibody against type I collagen was purchased from Abcam (ab21286). The sections were stained with MOMA-2 or 1A4 followed by biotin-conjugated goat anti-rat IgG (for MOMA-2) or rabbit anti-mouse IgG (for α-SMA, 1A4) followed by streptavidin-biotin peroxidase complex (Histofine kit; Nichirei). The sections were stained with an antibody against type I collagen, followed by horse radish peroxidase (HRP)-conjugated goat anti-rabbit IgG. The sections were subsequently counterstained with hematoxylin.

Lipid measurements and serum immunoglobulin titration

Serum levels of total cholesterol (Determiner TC555; KYOWA MEDEX), triglycerides (Determiner TG; KYOWA MEDEX), and high density lipoprotein (HDL) cholesterol (Determiner HDL; KYOWA MEDEX) were measured. Serum immunoglobulin (Ig) isotypes (IgG, IgG_1, IgG_{2a}, and IgM) and malondialdehyde (MDA)-low density lipoprotein (LDL)-specific antibodies were measured as described previously.[4] To quantify MDA-LDL-specific antibodies, plates were coated with 100 μg/mL

MDA-LDL, washed, and blocked; sera were subsequently added at an optimized 1:100, 1:1,000 or 1:10,000 dilutions, and specific detection antibodies for IgG_1, IgG_{2a} (BETHYL), IgG, and IgM (Jackson ImmunoResearch Laboratories) were added. MDA-LDL was prepared as described previously[5].

Cytokine analysis

Eight weeks or 16 weeks after HFD feeding, spleen cells were removed and single-cell suspensions were obtained by passing the cells through a 100-μm cell strainer. $CD4^+$ T cells were isolated from these cells using MACS separation columns (25 MS) with CD4 microbeads (L3T4; Miltenyi Biotec). These cells were stimulated in microwell cultures (6×10^5/well) with 20 ng/mL phorbol 12-myristate 13-acetate (PMA; Sigma-Aldrich) and 250 ng/mL ionomycin (Sigma-Aldrich) in RPMI 1640 medium supplemented with 10% FBS, 100 U/mL penicillin, and 100 μg/mL streptomycin (Wako). Supernatants were collected at 72 h and analyzed by ELISA for IFN-γ, IL-5, IL-4, IL-6, IL-10 (BD Biosciences), IL-17A (R & D Systems) and IL-17C (Uscn Life Science Inc).

Intracellular cytokine staining

Murine splenic $CD4^+$ T cells were cultured with 20 ng/mL PMA, 250 ng/mL ionomycin, and 1 μL/mL GolgiPlug (BD Biosciences) for 5.5 h. The cells were washed with FACS buffer (0.5% bovine serum albumin and 0.05% NaN_3 in PBS) and blocked with rat anti-mouse Fc receptor antibody, CD16/CD32 (2.4G2; BD Biosciences). The cells were then labeled with FITC-anti-CD3ε (145-2C11; BioLegend) and PE/Cy5-anti-CD4 (RM4-5; BioLegend). Next, the cells were fixed and permeabilized with BD Cytofix/Cytoperm (BD Biosciences). Intracellular cytokines were stained with PE-anti-IL-17A (BD Biosciences) and Alexa Fluor 647-anti IFN-γ (XMG1.2; BioLegend). All analyses were performed on a FACS Calibur flow cytometer (BD Biosciences) with FlowJo software (Tree Star).

Experimental design for exogenous IL-17A administration

$ApoE^{-/-}$ mice at ages of 6-8 weeks, fed the HFD for 12 weeks were used in this study. Additionally, $ApoE^{-/-}IL\text{-}17A^{-/-}$ mice at ages of 5 weeks, fed the HFD for 10 weeks were used. Both groups of mice were treated with recombinant mouse IL-17A (eBioscience) (2 μg/mouse) diluted in PBS 0.05% mouse albumin (Sigma) (200 μL/mouse) or PBS 0.05% albumin twice a week during HFD feeding.

Statistical analysis

Results are expressed as mean (SEM). Statistical significance between groups was estimated using Student's *t*-test; $p < 0.05$ was considered statistically significant.

Supplemental Figure Legends

Supplemental Figure I. IL-17A deficiency did not affect atherosclerotic plaque formation in ApoE$^{-/-}$ mice under normal chow diet feeding.

Atherosclerotic plaque formation was quantitatively analyzed by staining of aortae with oil red O. ApoE$^{-/-}$ and ApoE$^{-/-}$IL-17A$^{-/-}$ mice: day 0 (n = 5; each group), 8 weeks after normal chow diet feeding (normal diet 8w; n =4 and 3, respectively), 16 weeks after normal chow diet feeding (normal diet16w; n = 6; each group). *$p < 0.05$. **$p < 0.005$. N.S. denotes difference between two groups is not significantly different.

Supplemental Figure II. Atherosclerotic plaque area of abdominal aorta area was decreased in ApoE$^{-/-}$IL-17A$^{-/-}$ mice compared to ApoE$^{-/-}$ mice.

A, Representative microphotographs of abdominal aortic sections stained with H&E in ApoE$^{-/-}$ and ApoE$^{-/-}$IL-17A$^{-/-}$ mice after 8 weeks of HFD feeding. Scale bars indicate 30 μm. B, Quantitative analysis of plaque areas in both ApoE$^{-/-}$ (n= 8) and ApoE$^{-/-}$IL-17A$^{-/-}$ (n= 8) mice. *$p < 0.05$.

Supplemental Figure III. Type I collagen-positive area was decreased in ApoE$^{-/-}$IL-17A$^{-/-}$ mice compared to ApoE$^{-/-}$ mice

A, Representative microphotographs of aortic root sections stained with type I collagen in ApoE$^{-/-}$ and ApoE$^{-/-}$IL-17A$^{-/-}$ mice after 8 weeks of HFD feeding. Scale bars in upper panels indicate 300 μm and in under panels indicate 50 μm. B, Quantitative analysis of the percentage of type I collagen-positive areas in both ApoE$^{-/-}$ (n= 4) and ApoE$^{-/-}$IL-17A$^{-/-}$ (n= 11) mice. *$p < 0.05$.

Supplemental Figure IV. IL-17A deficiency did not significantly affect IL-4, IL-6, IL-10, and IL-17C production in ApoE$^{-/-}$ mice.

Quantitative analysis of IL-4 (A), IL-6 (B), IL-10(C), and IL-17C (D) production in the supernatants of splenic CD4-positive T cells from ApoE$^{-/-}$ and ApoE$^{-/-}$IL-17A$^{-/-}$ mice before (n= 4 and 6, respectively) and after 8 (n= 5 and 8, respectively) or 16 (n= 4 and 7, respectively) weeks of HFD feeding. Splenic CD4-positive T cells were cultured *in vitro* with PMA and ionomycin; culture supernatants were examined by ELISA. Data were obtained from at least three independent experiments. *$p < 0.05$. N.D. denotes not detectable.

Supplemental Figure V. IL-17A deficiency did not significantly affect production of MDA-LDL-specific IgG_{2a}, IgG, and IgM antibodies in $ApoE^{-/-}$ mice after HFD feeding.

Quantitative analysis of titers of MDA-LDL-specific antibodies, IgG2a(A), IgG(B), and IgM(C) in $ApoE^{-/-}$ (n= 21) and $ApoE^{-/-}IL\text{-}17A^{-/-}$ (n= 35) mice before and after 8 or 16 weeks of HFD feeding. Values are indicated by the relative protein levels against MDA-LDL-specific antibody titers of $ApoE^{-/-}$ mice at day 0 and value at day 0 was set as 1. $*p < 0.05$. $***p < 0.0005$. N.S., not significantly different. Note that only IgM class of anti- MDA-LDL antibody was reduced in $ApoE^{-/-}IL\text{-}17A^{-/-}$ compared to $ApoE^{-/-}$ mice at 16 weeks after HFD feeding.

References

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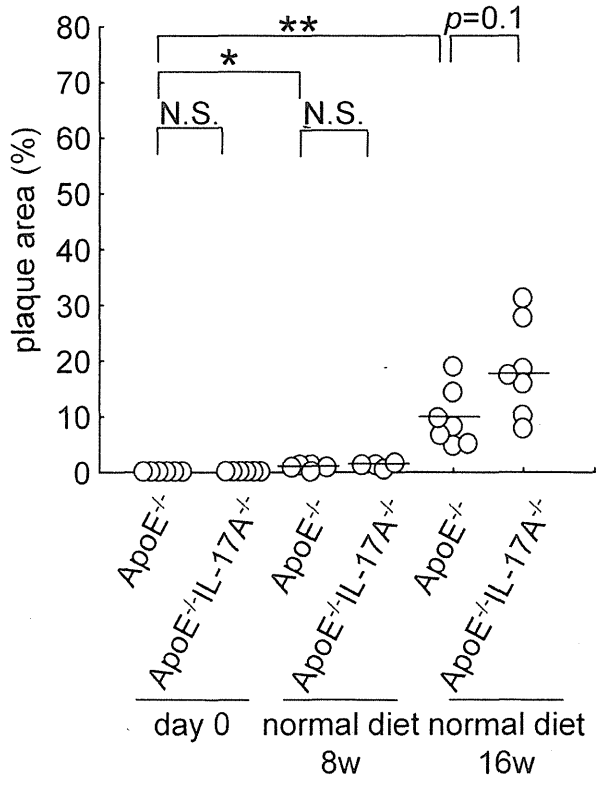
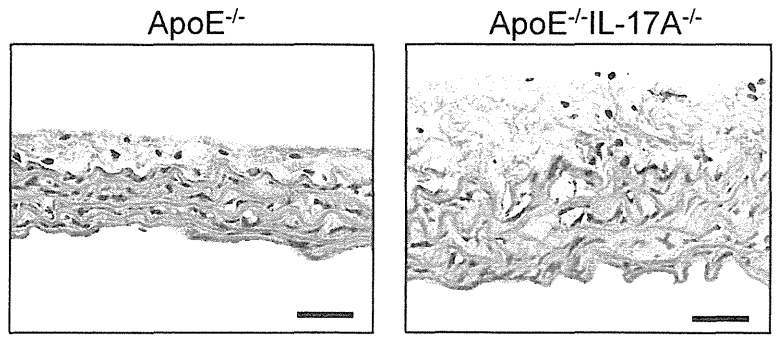


Supplemental Figure I

A



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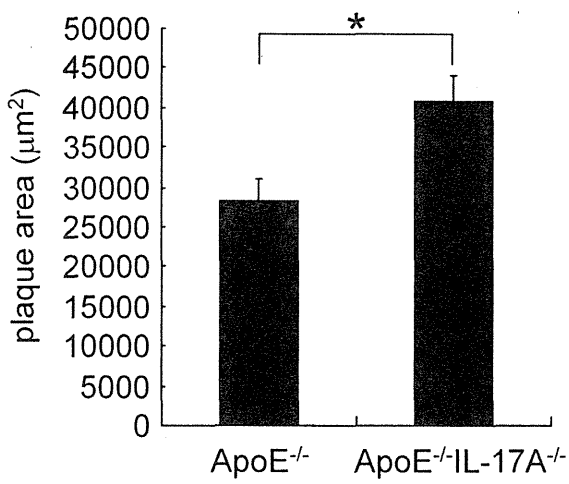
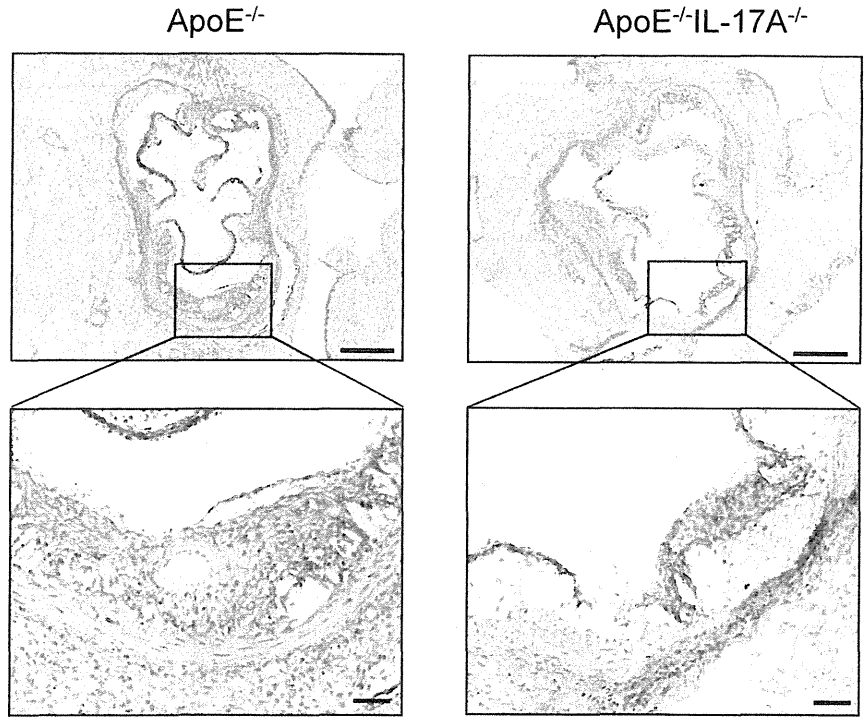


Supplemental Figure II

A



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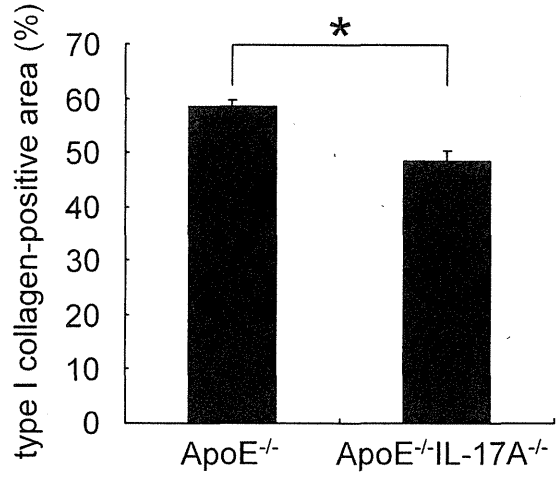

Supplemental Figure III