(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
25 July 2013 (25.07.2013)

WIPO | PCT

(10) International Publication Number
WO 2013/109342 A1

(51) **International Patent Classification**:
A61K 38/17 (2006.01) *A61P 3/10* (2006.01)
C07K 14/775 (2006.01)

(21) **International Application Number**:
PCT/US2012/066314

(22) **International Filing Date**:
21 November 2012 (21.11.2012)

(25) **Filing Language**: English

(26) **Publication Language**: English

(30) **Priority Data**:
PCT/US2012/0021802
19 January 2012 (19.01.2012) US
61/675,692 25 July 2012 (25.07.2012) US

(71) **Applicant**: **UNIVERSITY OF CINCINNATI** [US/US]; 51 Goodman Dr., Suite 240, Cincinnati, OH 45221 (US).

(72) **Inventors**: **TSO, Patrick**; 51 Goodman Dr., Suite 240, Cincinnati, OH 45242 (US). **WANG, Fei**; 10811, Fallsington Court, Cincinnati, OH 45242 (US). **DAVIDSON, Sean**; 51 Goodman Dr., Suite 240, Cincinnati, OH 45221 (US).

(74) **Agents**: **DAVIS, Steven, G.** et al.; McCarter & English, LLP, 265 Franklin Street, Boston, MA 02110 (US).

(81) **Designated States** *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) **Designated States** *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*

— *with sequence listing part of description (Rule 5.2(a))*

WO 2013/109342 A1

(54) **Title**: METHOD OF TREATING DIABETES USING NON-GLYCOSYLATED APOLIPOPROTEIN A-IV

(57) **Abstract**: Methods for treating type two diabetes mellitus in a subject in need thereof and pharmaceutical compositions for the treatment of type two diabetes mellitus are disclosed, wherein the methods and compositions of the invention are based on the use of non-glycosylated apolipoprotein A-IV produced by a protein expression system, such as a bacterial expression system. Also disclosed are methods for substantially restoring glucose tolerance in a subject in need thereof to a normal level and methods for lowering blood glucose levels in a subject in need thereof based on administering non- glycosylated apolipoprotein A-IV produced by a protein expression system.

METHOD OF TREATING DIABETES USING NON-GLYCOSYLATED APOLIPOPROTEIN A-IV

TECHNICAL FIELD

[0001] The present disclosure relates to a method of treating diabetes using non-glycosylated apolipoprotein A-IV (apoA-IV). More particularly, the present disclosure relates to a method of treating type two diabetes mellitus by administering an effective amount of non-glycosylated apoA-IV which is produced by a protein expression system.

RELATED APPLICATIONS

[0002] This application claims priority to PCT Appln. No. PCT/US2012/021802, filed on January 19, 2012. This application also claims priority to U.S. Provisional Patent Appln. No. 61/675692, filed on July 25, 2012. The entire contents of the priority applications are incorporated herein by reference in their entirety.

BACKGROUND

[0003] The occurrence of diabetes is widespread, with approximately 8% of the population in the United States suffering from diabetes. Diabetes is a chronic disease characterized by high blood sugar due to the body's inability to effectively produce and/or use insulin. Diabetes can lead to a variety of physical complications, including but not limited to renal failure, blindness, nerve damage, heart disease, sleep apnea, and celiac disease. For example, in the United States, diabetes is the leading cause of renal failure, blindness, amputation, stroke, and heart attack. Also in the United States, diabetes is the sixth leading cause of death and has been shown to reduce the life expectancy of middle-aged adults by about five to ten years.

[0004] The most common form of diabetes is type 2 diabetes mellitus (also referred to as "T2DM" or “type 2 diabetes”). Type 2 diabetes is characterized by hyperglycemia, insulin resistance, β-cell dysfunction, and dysregulated hepatic gluconeogenesis. Persons suffering from type 2 diabetes experience a loss of glucose-stimulated insulin secretion related to the impaired release of stored insulin granules from β-cells in the

first phase of insulin secretion. In the second phase of insulin secretion, persons suffering from type 2 diabetes experience a gradual loss of the ability to actively synthesize insulin in response to glucose stimuli.

[0005] The prevalence of type 2 diabetes is increasing and in 2002, type 2 diabetes resulted in greater than $130 billion in health care expenses. As such, new therapies for effectively treating type 2 diabetes are needed.

SUMMARY

[0006] The invention is based on the surprising discovery that the apolipoprotein A-IV (apoA-IV) protein is non-glycosylated in humans. Prior to the present disclosure, it was known in the art that the apoA-IV protein was glycosylated. Weinberg and Scanu ((1983) *J of Lipid Res* vol. 24:52) reported that apoA-IV was a glycoprotein containing 6% carbohydrate by weight (mannose 1.8%, galactose 1.55%, N-acetyl glucosamine 1.55%, sialic acid 1.1%). As such, apoA-IV is commonly described as a glycoprotein (see, for example, Gomaraschi *et al.* (2010) *Biochem Biophys Res Commun.* 393(1):126-30). In contrast, as described in Example 13 below, apoA-IV is a non-glycosylated protein.

[0007] Thus, in one embodiment, the invention provide methods of treating type 2 diabetes using non-glycosylated (also referred to as unglycosylated) apoA-IV protein. The method comprises administering to the subject an effective amount of a non-glycosylated apoA-IV protein, or a biologically active analogue or fragment thereof having at least 90, 95, 96, 97, 98 or 99% identity to the apoA-IV protein.

[0008] In one embodiment, non-glycosylated apoA-IV is produced using an expression system which lacks the ability to glycosylate. For example, a bacterial expression system, such as *Escherichia coli,* may be used to make non-glycosylated apoA-IV.

[0009] In another embodiment, cell expression systems that may be used to make non-glycosylated apoA-IV include, but are not limited to, mammalian cell expression systems, yeast expression systems and baculovirus expression systems. In another embodiment, a cell free expression system may be used to make non-glycosylated apoA-IV protein.

[0010] In another embodiment, a pharmaceutical composition comprising non-glycosylated apoA-IV protein is disclosed. The pharmaceutical composition comprises non-glycosylated apoA-IV protein having at least 90, 95, 96, 97, 98 or 99% identity to the apoA-IV protein, or a biologically active fragment thereof. The pharmaceutical composition may be formulated for administration to a subject for the treatment of type 2 diabetes.

[0011] In one embodiment, the invention provides a pharmaceutical composition comprising a non-glycosylated apoA-IV protein comprising an amino acid sequence as set forth in any one of SEQ ID NOs: 1, 3, 4, or 20 to 64 (or a sequence that is at least 90, 95, 96, 97, 98 or 99% identical to SEQ ID NO: 1, 3, 4, or 20-64), or a biologically active fragment thereof. In one embodiment, the invention provides a pharmaceutical composition comprising non-glycosylated apolipoprotein A-IV protein comprising an amino acid sequence as set forth in any one of SEQ ID NOs: 1, 3, 4, or 20-64, or an amino acid sequence which is at least 95% identical to any one of SEQ ID NOs: 1, 3, 4, or 20-64, or a biologically active fragment thereof. In another embodiment, the invention provides a pharmaceutical composition having an apolipoprotein A-IV protein comprising an amino acid sequence which is at least 96% identical to any one of SEQ ID NOs: 1, 3, 4, or 20-64, or a biologically active fragment thereof. In another embodiment, the invention provides a pharmaceutical composition having an apolipoprotein A-IV protein comprising an amino acid sequence which is at least 97% identical to any one of SEQ ID NOs: 1, 3, 4, or 20-64, or a biologically active fragment thereof. In another embodiment, the invention provides a pharmaceutical composition having an apolipoprotein A-IV protein comprising an amino acid sequence which is at least 98% identical to any one of SEQ ID NOs: 1, 3, 4, or 20-64, or a biologically active fragment thereof. In another embodiment, the invention provides a pharmaceutical composition having an apolipoprotein A-IV protein comprising an amino acid sequence which is at least 99% identical to any one of SEQ ID NOs: 1, 3, 4, or 20-64, or a biologically active fragment thereof.

[0012] In one embodiment, the pharmaceutical composition comprises a pharmaceutically acceptable carrier or diluent.

[0013] In another embodiment, the pharmaceutical composition is selected from the group consisting of a liquid formulation, an aqueous formulation, and a lyophilized formulation.

[0014] In one embodiment, the invention provides a method of treating type 2 diabetes comprising administering to a subject having type 2 diabetes a non-glycosylated apoA-IV protein, or a biologically active analogue or fragment thereof, having an amino acid sequence comprising an amino acid sequence as set forth in any one of SEQ ID NOs: 1, 3, 4, or 20 to 64 (or a sequence that is at least 90, 95, 96, 97, 98 or 99% identical to SEQ ID NO: 1, 3, 4, or 20-64). In a further embodiment, the apoA-IV protein is produced using a prokaryotic expression system, e.g., bacterial expression system such as *E. coli*.

[0015] In yet another embodiment, a method for substantially restoring glucose tolerance in a subject in need thereof to a normal level is disclosed. The method comprises administering to the subject an effective amount of non-glycosylated apoA-IV or a biologically active analogue or fragment thereof, having at least 90, 95, 96, 97, 98 or 99% identity to an apoA-IV protein, for example, by systemic administration of the non-glycosylated apoA-IV or the biologically active analogue or fragment thereof. In one embodiment, the invention provides a method for substantially restoring glucose tolerance in a subject in need thereof to a normal level, said method comprising administering an effective amount of a non-glycosylated apoA-IV protein (or a biologically active analogue or fragment thereof) having an amino acid sequence as set forth in any one of SEQ ID NOs: 1, 3, 4, or 20 to 64 (or an amino acid sequence that is at least 90, 95, 96, 97, 98 or 99% identical to SEQ ID NO: 1, 3, 4, or 20-64)..

[0016] In yet still another embodiment, a method for lowering blood glucose level in a subject in need thereof is disclosed. The method comprises administering to the subject an effective amount of non-glycosylated apoA-IV or a biologically active analogue or fragment thereof having at least 90, 95, 96, 97, 98 or 99% identity to the non-glycosylated apoA-IV to the subject in need, for example, by systemic administration. In one embodiment, the invention provides a method for lowering blood glucose level in subject a subject in need thereof, the method comprising administering to the subject an effective amount of non-glycosylated apoA-IV (or a biologically active analogue or fragment thereof) comprising an amino acid sequence set forth in SEQ ID NOs: 1, 3, 4,

or 20 to 64 (or a sequence that is at least 90, 95, 96, 97, 98 or 99% identical to SEQ ID NO: 1, 3, 4, or 20-64).

[0017] An "effective amount" is as described below and may include about 0.25 to 2 μg/g of the apoA-IV or the biologically active analogue thereof. In one embodiment the effective amount is about 0.1 mg/kg to 25 mg/kg. In another embodiment, the effective amount is a fixed dose of about 1 to 1000 mg. In a further embodiment, the effective amount is a fixed dose of about 1 to 10 mg.

[0018] These and other features and advantages of these and other various embodiments according to the present disclosure will become more apparent in view of the drawings, detailed description, and claims provided herein.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] The following detailed description of the embodiments of the present disclosure can be better understood when read in conjunction with the following drawings, where like structure is indicated with like reference numerals, and in which:

[0020] FIG. 1 is a side perspective view of a device having a reservoir of a pharmaceutical composition and a syringe according to an embodiment of the present disclosure.

[0021] FIG. 2 is a graph of plasma glucose (mg/dL) in male apoA-IV knockout and wild-type mice with respect to time (min) for an intraperitoneal glucose tolerance test.

[0022] FIG. 3 is a graph of plasma glucose (mg/dL) with respect to time (min) for an intraperitoneal glucose tolerance test in apoA-IV wild-type and knockout animals at 16 months of age.

[0023] FIG. 4 is a graph of plasma glucose (mg/dL) with respect to time (min) in male apoA-IV knockout mice following the intraperitoneal administration of recombinant apoA-IV (μg/g) or saline solution for an intraperitoneal glucose tolerance test.

[0024] FIG. 5 is a graph of plasma glucose (mg/dL) with respect to time (min) in apoA-IV knockout mice following the intraperitoneal administration of recombinant apoA-I or saline solution for an intraperitoneal glucose tolerance test.

[0025] FIG. 6 is a graph of insulin secretion (ng/mL) with respect to time (min) in apoA-IV knockout mice following the intraperitoneal administration of recombinant apoA-I or saline solution.

[0026] FIG. 7 is graph of plasma glucose (mg/mL) with respect to time (min) in apoA-IV knockout and wild-type mice on a chronically high-fat diet for an intraperitoneal glucose tolerance test.

[0027] FIG. 8 is a graph of plasma glucose (mg/mL) with respect to time (min) in apoA-IV knockout mice on a chronically high-fat diet following the intraperitoneal administration of recombinant mouse apoA-IV (1 μg/g) or saline solution for an intraperitoneal glucose tolerance test.

[0028] FIG. 9 is a graph of plasma glucose (mg/dL) with respect to time (h) in diabetic mice following the intraperitoneal administration of recombinant mouse apoA-IV (1 μg/g) or saline solution for an intraperitoneal glucose tolerance test.

[0029] FIG. 10 depicts the results of a Western blot analysis of the level of serum amyloid A protein component in apoA-IV knockout mice, wild-type mice, and apoA-I knockout mice.

[0030] FIG. 11 is a graph of plasma glucose (mg/dL) in female apoA-IV knockout and wild-type mice with respect to time (min) during an intraperitoneal glucose tolerance test (IPGTT).

[0031] FIG 12. is a graph of plasma glucose (mg/dL) with respect to time (min) in wild type mice following the intraperitoneal administration of 1.0 μg/g human apoA-IV or saline solution during an intraperitoneal glucose tolerance test.

[0032] FIG. 13 is a graph of plasma glucose (mg/dL) with respect to time (min) in female wild type mice following the intraperitoneal administration of 1.0 μg/g recombinant mouse apoA-IV or saline solution during an intraperitoneal glucose tolerance test.

[0033] FIG. 14 is a bar graph showing the effect of 10 μg/g human apoA-IV on human islets depolarized by 30mM KCl and 250μM diazoxide in the presence of 3mM or 20mM glucose.

[0034] FIG. 15 is a protein with the amino acid sequence of full length wild type human apoA-IV (SEQ ID NO. 1).

[0035] FIG. 16 is a protein with the amino acid sequence of full length wild type mouse apoA-IV (SEQ ID NO. 2).

[0036] FIG. 17 is a protein having the amino acid sequence of full length wild type human apoA-IV with the addition of glycine at the *N*-terminus (SEQ ID NO. 3).

[0037] FIG. 18 is a protein with the amino acid sequence of human apoA-IV showing polymorphic substitutions T347S, Q360H, and/or E165K and the optional addition of glycine, alanine or valine to the *N*-terminus (SEQ ID NO. 4).

[0038] FIG. 19 is a polynucleotide (SEQ ID NO. 5) encoding full length wild type human apolipoprotein A-IV.

[0039] FIG. 20 includes the amino acid sequence and optimized nucleotide coding sequence of the Omp-Apo A-IV construct for periplasmic expression in *E. coli*.

[0040] FIG. 21 includes the amino acid sequence and optimized nucleotide coding sequence of PelB-Apo A-IV construct for periplasmic expression in *E. coli*.

[0041] FIG. 22 includes the amino acid sequence and optimized nucleotide coding sequence of ENX-Apo A-IV construct for periplasmic expression in *E. coli*.

[0042] FIG. 23 includes the amino acid sequence and optimized nucleotide coding sequence of Apo A-IV construct for cytoplasmic expression in *E. coli*.

[0043] FIGS. 24A and B show N-glycosylation prediction results for the human wild type apoA-IV (FIG 24A) and variant P393H (FIG 24B).

[0044] FIGS.25A and B shows O-glycosylation prediction results for the human wild type apoA-IV (FIG. 25A) and variant P393H (FIG. 25B).

[0045] Skilled artisans appreciate that elements in the figures are illustrated for simplicity and clarity and are not necessarily drawn to scale. For example, the dimensions of some of the elements in the figures may be exaggerated relative to other elements, as well as conventional parts removed, to help to improve understanding of the various embodiments of the present disclosure.

DETAILED DESCRIPTION

[0046] The following terms are used in the present application:

[0047] As used herein, the term “non-glycosylated” or "unglycosylated" means a protein without observable N-linked glycosylation and/or O-linked glycosylation, within the limits of detection, for example, by isoelectric focusing, PNGase F digestion and/or MALDI analysis. In one embodiment, the term “non-glycosylated” or "unglycosylated" means without observable N-linked glycosylation and without observable O-linked glycosylation. In another embodiment, the term “non-glycosylated” or "unglycosylated" means without observable N-linked glycosylation. In another embodiment, the term “non-glycosylated” or "unglycosylated" means without observable O-linked glycosylation.

[0048] As used herein, the term “protein expression system” refers to a cell-based or non-cell-based expression system that is used to produce a protein of interest, *e.g.,* apoA-IV. Given that apoA-IV has been surprisingly found to lack glycosylation, expression systems that lack glycosylation machinery may be used to produce the protein for use in the treatment of type II diabetes. In one embodiment, cell-based expression systems which do glycosylate, such as mammalian cells, may be used to produce non-glycosylated apoA-IV. In one embodiment, the protein expression system used to make apoA-IV includes either a bacterial expression system, a mammalian cell expression system, a baculovirus (insect) cell expression system, or a yeast expression system.

[0049] The term "recombinant host cell" (or simply "host cell"), as used herein, refers to a cell that has been transformed, or is capable of being transformed, with a nucleic acid sequence and thereby expresses a gene of interest, e.g., apoA-IV. It should be understood that such terms are intended to refer not only to the particular subject cell but to the progeny of such a cell. Because certain modifications may occur in succeeding generations due to either mutation or environmental influences, such progeny may not, in fact, be identical to the parent cell, but are still included within the scope of the term "host cell" as used herein. Host cells may be prokaryotic or eukaryotic cells that are capable of expressing exogenous nucleic acid sequences. Examples of host cells include bacteria such as E. coli, yeast, plant cells, Chinese hamster ovary (CHO) cells, human embryonic kidney (HEK)-293 cells and insect cells.

[0050] The term "isolated" as it is used in reference to a protein, is a protein, polypeptide or antibody that by virtue of its origin or source of derivation: (1) is not associated with naturally associated components that accompany it in its native state; (2) is free of other proteins from the same species; (3) is expressed by a cell from a different species; or (4) does not occur in nature. Thus, a polypeptide that is, e.g., chemically synthesized or synthesized in a cellular system different from the cell from which it naturally originates will be "isolated" from its naturally associated components. A protein may also be rendered substantially free of naturally associated components by isolation, using any suitable protein purification technique. In one embodiment, the apoA IV protein used in the compositions and methods of the invention is an isolated protein obtained from a recombinant host cell, e.g., a bacterial cell.

[0051] The phrase "percent identical" or "percent identity" refers to the similarity (e.g., 95%, 96%, 97%, 98%, or 99%) between at least two different sequences. This percent identity can be determined by standard alignment algorithms, for example, the Basic Local Alignment Search Tool (BLAST) described by Altshul et al. ((1990) J. Mol. Biol. 215:403-10); the algorithm of Needleman et al. ((1970) J. Mol. Biol. 48:444-53); or the algorithm of Meyers et al. ((1988) Comput. Appl. Biosci. 4:11-17). A set of parameters may be, for example, the Blosum 62 scoring matrix with a gap penalty of 12, a gap extend penalty of 4, and a frameshift gap penalty of 5. The percent identity between two amino acid or nucleotide sequences can also be determined using the algorithm of Meyers and Miller ((1989) CABIOS 4:11-17), which has been incorporated into the ALIGN program (version 2.0), using a PAM120 weight residue table, a gap length penalty of 12, and a gap penalty of 4.

[0052] The term "recombinant protein" refers to a protein molecule that is expressed from recombinant DNA. For example, a recombinant ApoA-IV protein is one that is expressed in a recombinant host cell. Preferably, the ApoA-IV protein used in the methods and compositions of the invention is a recombinant ApoA-IV protein.

[0053] As used herein, the term "effective amount" describes the amount necessary or sufficient to realize a desired biologic effect. The effective amount for any particular application may vary depending on a variety of factors, including but not limited to the particular composition being administered, the size of the subject, and/or the severity of the disease and/or condition being treated. In one embodiment, an “effective amount” is

a dose of about 0.25 to 10 μg/g of a non-glycosylated apoA-IV or biologically active analogue thereof. Alternatively, an "effective amount of a non-glycosylated apoA-IV or a biologically active analogue thereof is about 1 to 10 μg/g, about 0.25 to 2 μg/g, about 1 μg/g, or 0.1 mg/kg to 25 mg/kg. In another embodiment, the effective amount is a fixed dose of about 1 to 1000 mg. In a further embodiment, the effective amount is a fixed dose of about 1 to 10 mg.

[0054] Non-glycosylated apoA-IV or a biologically active analogue is administered one time daily. Alternatively, non-glycosylated apoA-IV or a biologically active analogue thereof is administered about 2 times per day. In yet another alternative, non-glycosylated apoA-IV or a biologically active analogue thereof is administered more than twice a day, for example, three times per day. In yet another alternative, non-glycosylated apoA-IV is administered once every second, third, fourth, fifth or sixth day, or once weekly.

[0055] As used herein, the term "desired biologic effect" describes reducing the effects of, counteracting, and/or eliminating a disease or condition. For example, in the context of type 2 diabetes, desired biologic effects include, but are not limited to lowering blood glucose, improving glucose tolerance, substantially restoring glucose tolerance to a normal level, improving insulin secretion, and/or substantially restoring insulin secretion to a normal level.

[0056] As used herein, the term "normal level" describes a level that is substantially the same as the level in a subject who is not in need of treatment. For example, in the context of treating type 2 diabetes, a normal level of blood glucose is from about 70 mg/dL to about 130 mg/dL before meals and less than about 180 mg/dL about one to two hours after meals, or from about 70 mg/dL to about 100 mg/dL before meals and less than about 140 mg/dL about one to two hours after meals. In another example in the context of treating type 2 diabetes, a normal level of glucose tolerance describes the ability of the subject to metabolize carbohydrates such that the level of blood glucose is from about 70 mg/dL to about 130 mg/dL before meals and less than about 180 mg/dL about one to two hours after meals, or from about 70 mg/dL to about 100 mg/dL before meals and less than about 140 mg/dL about one to two hours after meals. In still another example in the context of treating type 2 diabetes, the normal level of insulin secretion is the amount required to maintain a normal level of glucose tolerance, wherein the level of

insulin secretion is greater than about 1 ng/mL about fifteen hours after meals. In a further embodiment, a normal level of blood glucose is from about 70 mg/dl to 100 mg/dl for a morning fasting blood sugar test.

[0057] In the context of blood glucose level, the term "restore" describes changing the blood glucose level of a subject to a normal level. Similarly, in the context of glucose tolerance, the term "restore" describes changing the glucose tolerance of a subject to a normal level. Also, in the context of insulin secretion, "restore" describes changing the insulin secretion of a subject to a normal level.

[0058] In the context of non-glycosylated apoA-IV, the term "biologically active fragment" describes a fragment of non-glycosylated apoA-IV which is capable of realizing a desired biologic effect in a subject with type 2 diabetes. The term "biologically active analogue" describes an analogue of non-glycosylated apoA-IV which is capable of realizing a desired biologic effect in a subject with type 2 diabetes. In one example, a desired biological effect is to restore glucose tolerance in apoA-IV knockout mice as described in Example 2. Another example of a desired biological effect is to cause a statistically significant lowering of abnormal glucose levels in an animal model of type 2 diabetes, such as the mouse model described in Example 7.

[0059] As used herein, the term "obese" describes a condition in which a subject is well above a normal weight. In one specific example, the term obese describes a condition in which a subject is more than about 20% over their ideal weight and/or has a body mass index of about thirty or greater than about thirty. In one embodiment, the subject being treated is obese; in another embodiment, the subject being treated is not obese; and in yet another embodiment, the subject being treated has a normal body weight.

[0060] Embodiments of the present disclosure relate to methods for treating type 2 diabetes in a subject in need thereof and pharmaceutical compositions for the treatment of type 2 diabetes. In one embodiment, a method of treating diabetes is disclosed. In one particular embodiment, a method of treating type 2 diabetes in a subject in need thereof is disclosed, wherein the method comprises administering an effective amount of non-glycosylated apolipoprotein A-IV (hereinafter "apoA-IV") or a biologically active analogue or fragment thereof to the subject.

[0061] In one embodiment, the method of treating type 2 diabetes is effective to lower blood glucose level of a subject. In one particular embodiment, the method is effective to lower blood glucose level of a subject by about 20 to 50%. In a further embodiment, the method is effective to lower the blood glucose level of a subject by about 40%. In a further embodiment, the method is effective to lower the blood glucose level of a subject by about 70 %. In still a further embodiment, the method is effective to substantially restore blood glucose level to a normal level.

[0062] In one embodiment, the method of treating type 2 diabetes results in a lower blood glucose level of a subject. In one particular embodiment, the method is effective to lower blood glucose level of a subject by about 1 mg/dl, 2 mg/dl, 3 mg/dl, 4 mg/dl, 5 mg/dl, 6 mg/dl, 7 mg/dl, 8 mg/dl, 9 mg/dl, 10 mg/dl, 11 mg/dl, 12 mg/dl, 13 mg/dl, 14 mg/dl, 15 mg/dl, 16 mg/dl, 17 mg/dl, 18 mg/dl, 19 mg/dl, 20 mg/dl, 40 mg/dl, 60 mg/dl, 80 mg/dl, 100 mg/dl, 120 mg/dl, 140 mg/dl, 160 mg/dl, 180 mg/dl, 200 mg/dl, 220 mg/dl, or 240 mg/dl, from a baseline level over the course of the dosing interval.

[0063] In another embodiment, the method of treating type 2 diabetes is effective to substantially restore glucose tolerance of a subject to a normal level. In one particular embodiment, the method is effective to substantially restore glucose tolerance of a subject to a normal level within about two hours after administration of a dose of non-glycosylated apoA-IV or a biologically active analogue thereof . In another embodiment, the method is effective to substantially restore glucose tolerance of a subject to a normal level within about three hours or within about four hours after administration of a dose of an apoA-IV or a biologically active analogue thereof . In another embodiment, the glucose tolerance of a subject is substantially restored to a normal level for about eight to twelve hours.

[0064] In yet another embodiment, the treatment is effective to substantially restore insulin secretion to a normal level. In one particular embodiment, the treatment is effective to substantially restore insulin secretion to a normal level within about two hours after the administration of a dose of non-glycosylated apoA-IV or a biologically active analogue or fragment thereof . In another embodiment, insulin secretion is substantially restored to a normal level for about eight to twelve hours. In still another embodiment, the treatment is effective to lower the level of C-reactive protein.

[0065] In one embodiment, non-glycosylated apoA-IV or a biologically active analogue thereof is administered systemically. Systemic administration of the non-glycosylated apoA-IV or the analogue thereof is selected from the group consisting of oral, subcutaneous, intravenous, intramuscular, and intraperitoneal administration.

[0066] In another embodiment, a pharmaceutical composition is disclosed. In one particular embodiment, the pharmaceutical composition comprises non-glycosylated apoA-IV or a biologically active analogue or fragment thereof. In another embodiment, the non-glycosylated apoA-IV or analogue thereof is formulated for administration to a subject for the treatment of type 2 diabetes. In this particular embodiment, a method for treating type 2 diabetes in a subject in need thereof is also provided, wherein the method comprises administering an effective amount of the pharmaceutical composition to the subject.

[0067] An "apolipoprotein A-IV" refers to mammalian apoA-IV and includes full-length apoA-IV and biologically active fragments of apoA-IV. The full-length human apoA-IV protein is a 376 amino acid protein (SEQ ID NO: 1), the amino acid sequence of which is shown in FIG. 15 and the molecular weight of which is 43.4 kDa . The amino acid sequence of full length mouse apoA-IV protein (SEQ ID NO. 2) is shown in FIG. 16. Also encompassed by the term "apolipoprotein A-IV" is the known analogue in which a glycine is added to *N*-terminus of the apoA-IV of the full length human sequence (SEQ ID NO. 3, as shown in FIG. 17), and analogues thereof having conservative substitutions for the *N*-terminal glycine (such as alanine and valine). An "apolipoprotein A-IV" also includes polymorphic forms thereof, including T347S, Q360H, or E165K substitutions to the human sequence represented by SEQ ID NO. 1 or the corresponding positions of SEQ ID NO. 3. As such, "apolipoprotein A-IV" includes the protein of SEQ ID NO. 4, shown in FIG. 18. In addition, human "apolipoprotein A-IV" includes variants (SEQ ID NOs: 20-64) each with a missense mutation: P393H, Q385K, Q381K, Q380H, Q377P, T367S, S353A, N352Y, V336M, D335H, G311R, V307L, R305C, R304Q, E291G, V274M, V274A, R264Q, A260T, E250K, N235S, Q231K, R220C, Q214H, E207K, T202M, R200C, D191N, D184N, P181L, A172T, R169W, A161S, R154W, T148M, S147N, A139E, N127K, S95L, R90C, T85A, Q77H, G74S, V13M, or V6M, as shown below in Table 1. SEQ ID NOs: 20-65 include the

signal sequence. In one embodiment, the methods and compositions described herein include the mature forms of the proteins described in SEQ ID NOS: 20-65.

[0068] In one embodiment, the methods and compositions described herein use a non-glycosylated ApoA-IV protein comprising an amino acid sequence selected from the group consisting of 1, 3, 4, or 20-64, or a biologically active fragment thereof. Alternatively, the methods and compositions described herein use a non-glycosylated ApoA-IV protein comprising an amino acid sequence having at least 95%, 96%, 97%, 98%, or 99% identity to a sequence selected from the group consisting of 1, 3, 4, or 20-64, or a biologically active fragment thereof.

[0069] A biologically active analogue of apoA-IV has at least 90, 95, 96, 97, 98 or 99% identity to an apoA-IV. As described in the previous paragraph, an apoA-IV includes full length mammalian apoA-IV (e.g., human or mammalian) (human is described in SEQ ID NO: 1), polymorphic forms thereof, the protein of SEQ ID NOS. 3 and 4, and biologically active fragments of any of the foregoing. Amino acid variations in the biologically active analogues preferably have conservative substitutions relative to the wild type sequences. A "conservative substitution" is the replacement of an amino acid with another amino acid that has the same net electronic charge and approximately the same size and shape. Amino acid residues with aliphatic or substituted aliphatic amino acid side chains have approximately the same size when the total number of carbon and heteroatoms in their side chains differs by no more than about four. They have approximately the same shape when the number of branches in their side chains differs by no more than one. Amino acid residues with phenyl or substituted phenyl groups in their side chains are considered to have about the same size and shape. Listed below are five groups of amino acids. Replacing an amino acid residue with another amino acid residue from the same group results in a conservative substitution:

> Group I: glycine, alanine, valine, leucine, isoleucine, serine, threonine, cysteine, and non-naturally occurring amino acids with C1-C4 aliphatic or C1-C4 hydroxyl substituted aliphatic side chains (straight chained or monobranched).
>
> Group II: glutamic acid, aspartic acid and non-naturally occurring amino acids with carboxylic acid substituted C1-C4 aliphatic side chains (unbranched or one branch point).

Group III: lysine, ornithine, arginine and non-naturally occurring amino acids with amine or guanidine substituted C1-C4 aliphatic side chains (unbranched or one branch point).

Group IV: glutamine, asparagine and non-naturally occurring amino acids with amide substituted C1-C4 aliphatic side chains (unbranched or one branch point).

Group V: phenylalanine, phenylglycine, tyrosine and tryptophan.

[0070] An apoA-IV or a biologically active analogue thereof is preferably unglycosylated. The preparation of recombinant unglycosylated human and mouse apoA-IV is described in Example 12. The polynucleotide sequence of full length wild type human apolipoprotein (SEQ ID NO. 1) is shown as SEQ ID NO. 5 in Figure 19.

[0071] ApoA-IV used in Examples 1-10 is unglycosylated. Non-glycosylated apoA-IV may be prepared according to standard methods known in the molecular biology field. For example, non-glycosylated apoA-IV may be prepared via traditional molecular cloning techniques.

[0072] In one embodiment, apoA-IV is prepared according to the methods described in Tubb et al. (2009) *J of Lipid Res* 50:1497, where the authors expressed recombinant apoA-IV with an affinity tag (Histidine (His) tag) in a bacterial expression system, i.e., E. coli. Tubb et al. describe the use of the tobacco etch virus (TEV) protease as a means for cleaving the His tag from the apoA-IV protein. Thus, the apoA-IV protein may be expressed in a recombinant host cell, e.g., E. coli, using a His tag which is cleaved by the TEV protease. Alternatively, the apoA-IV protein may be expressed in a recombinant host cell, e.g., E. coli, using a glutatione S-transferase (GST) tag which is cleaved by the TEV protease. In one embodiment, the TEV protease is used to cleave an affinity tag from the apoA-IV protein.

[0073] In one embodiment, a bacterial host may be used to produce unglycosylated apoA-IV. Examples of bacterial hosts include, but are not limited to, *E. coli* BL-21, BL-21 (DE3), BL21-AI™, BL21(DE3)pLysS, BL21(DE3)pLysE, BL21 Star™(DE3), and BL21 Star™ (DE3)pLysS, (Invitrogen). Corynebacterium may also be used as a host cell for expressing apoA-IV. Prior to transformation into the bacterial host, the DNA segment encoding ApoA-IV or its analogue may be incorporated in any of suitable

expression vectors for transformation into the bacterial host. Suitable expression vectors include plasmid vectors, cosmid vectors, and phage vectors variously known to those of skill in the art, for example, as described in Sambrook, et al., Molecular Cloning Manual, 2d Edition, 1989. Examples of the expression vector include pET Vectors (Invitrogen), pDEST vectors (Invitrogen), pRSET vectors (Invitrogen), and pJexpress Vector (DNA2.0 Inc.). In one embodiment, *E. Coli* BL-21 (DE3) is transformed with pET30 expression vector which contains the gene encoding the ApoA-IV.

[0074] In addition to prokaryotes, eukaryotic microbes such as filamentous fungi or yeast are suitable cloning or expression hosts for apoA-IV-encoding vectors. Saccharomyces cerevisiae, or common baker's yeast, is the most commonly used among lower eukaryotic host microorganisms. However, a number of other genera, species, and strains are commonly available and useful herein, such as Schizosaccharomyces pombe; Kluyveromyces hosts such as, e.g., K. lactis, K fragilis (ATCC 12,424), K. bulgaricus (ATCC 16,045), K. wickeramii (ATCC 24,178), K. waltii (ATCC 56,500), K. drosophilarum (ATCC 36,906), K. thermotolerans, and K. marxianus; yarrowia (EP 402,226); Pichia pastoris (EP 183,070); Candida; Trichoderma reesia (EP 244,234); Neurospora crassa; Schwanniomyces such as Schwanniomyces occidentalis; and filamentous fungi such as, e.g., Neurospora, Penicillium, Tolypocladium, and Aspergillus hosts such as A. nidulans and A. niger.

[0075] Suitable host cells for the expression of apoA-IV may also be derived from multicellular organisms. Examples of invertebrate cells include plant and insect cells. Numerous baculoviral strains and variants and corresponding permissive insect host cells from hosts such as Spodoptera frugiperda (caterpillar), Aedes aegypti (mosquito), Aedes albopictus (mosquito), Drosophila melanogaster (fruitfly), and Bombyx mori have been identified. A variety of viral strains for transfection are publicly available, e.g., the L-1 variant of Autographa californica NPV and the Bm-5 strain of Bombyx mori NPV, and such viruses may be used as the virus herein according to the present invention, particularly for transfection of Spodoptera frugiperda cells.

[0076] Plant cell cultures of cotton, corn, potato, soybean, petunia, tomato, and tobacco can also be utilized as hosts.

[0077] Another suitable host cell for production of apoA-IV protein is a vertebrate cell. Examples of useful mammalian host cell lines include, but are not limited to,

monkey kidney CV1 line transformed by SV40 (COS-7, ATCC CRL 1651); human embryonic kidney line (e.g., 293 or 293 cells subcloned for growth in suspension culture, Graham et al., J. Gen Virol. 36:59 (1977)); baby hamster kidney cells (BHK, e.g., ATCC CCL 10); Chinese hamster ovary cells/-DHFR(CHO, Urlaub et al., Proc. Natl. Acad. Sci. USA 77:4216 (1980)), including, but not limited to CHO K1, CHO pro3.sup.-, CHO DG44, CHO DUXB11, Lec13, B-Ly1, and CHO DP12 cells, preferably a CHO DUX (DHFR-) or subclone thereof (herein called "CHO DUX"); C127 cells, mouse L cells; Ltk.sup.- cells; mouse sertoli cells (TM4, Mather, Biol. Reprod. 23:243-251 (1980)); monkey kidney cells (CV1 ATCC CCL 70); African green monkey kidney cells (VERO-76, ATCC CRL-1587); human cervical carcinoma cells (HeLa, ATCC CCL 2); canine kidney cells (MDCK, ATCC CCL 34); buffalo rat liver cells (BRL 3A, ATCC CRL 1442); human lung cells (W138, ATCC CCL 75); human liver cells (Hep G2, HB 8065); mouse myeloma cells; NS0; hybridoma cells such as mouse hybridoma cells; COS cells; mouse mammary tumor (MMT 060562, ATCC CCL51); TR1 cells (Mather et al., Annals N.Y. Acad. Sci. 383:44-68 (1982)); MRC 5 cells; FS4 cells; and a human hepatoma line (Hep G2).

[0078] Host cells are transformed with expression or cloning vectors for production of the apoA-IV protein, and cultured in conventional nutrient media modified as appropriate for inducing promoters, selecting transformants, or amplifying the genes encoding the desired sequences.

[0079] ApoA-IV knockout mice used in the examples were generated according to procedures disclosed in J Lipid Res. 1997 Sep;38(9):1782-94, the entire teachings of which are incorporated herein by reference.

[0080] Also included in the methods of the invention are combination therapies for treating type 2 diabetes. Examples of additional therapeutic agents that may be used in combination with apolipoprotein A-IV include, but are not limited to, sulfonylureas, meglitinides, biguanides, thiazolidinediones, alpha-glucosidase inhibitors, DPP-4 inhibitors, incretin mimetics, and insulin. An additional therapeutic agent may be administered prior to, concurrently with, or subsequent to administration of apoA-IV to the subject in need thereof.

[0081] The effective amount or apoA-IV administered to a subject for the treatment of type 2 diabetes may, for example, be a weight-based dose (e.g., mg/kg) or, in another

example, be a fixed dose (non-weight dependent). In one embodiment, about 1 to 10 mg/kg, about 0.25 to 2 mg/kg, about 1 mg/kg, or 0.1 mg/kg to 25 mg/kg of apoA-IV is administered to a subject in need thereof. In another embodiment, the effective amount of apoA-IV administered to a subject in need thereof is a fixed dose of about 1 to 1000 mg. In a further embodiment, the effective amount is a fixed dose of apoA-IV administered to a subject in need thereof, is about 1 mg, 2 mg, 3 mg, 4 mg, 5 mg, 6 mg, 7 mg, 8 mg, 9 mg, 10 mg, 11, mg, 12 mg, 13 mg, 14 mg, 15 mg, 16 mg, 17 mg, 18 mg, 19 mg, 20 mg, 21 mg, 22 mg, 23 mg, 24 mg, 25 mg, 26 mg, 27 mg, 28 mg, 29 mg, 30 mg, 40 mg, 50 mg, 60 mg, 70 mg, 80 mg, 90 mg, 100 mg, 120 mg, 140 mg, 160 mg, 180 mg, 200 mg, 250 mg, 300 mg, 350 mg, 400 mg, 450 mg, 500 mg, 550 mg 600 mg, 650 mg, 700 mg, 750 mg, 800 mg, 850 mg, 900 mg, 950 mg, or 1000 mg.

[0082] In one particular embodiment, the pharmaceutical composition may further comprise a pharmaceutically acceptable carrier. Pharmaceutically acceptable carriers include a wide range of known diluents (i.e., solvents), fillers, extending agents, binders, suspending agents, disintegrates, surfactants, lubricants, excipients, wetting agents and the like commonly used in this field. The pharmaceutical composition is preferably aqueous, i.e., is a liquid formulation, and preferably comprises pyrogen free water. These carriers may be used singly or in combination according to the form of the pharmaceutical preparation. The resulting preparation may incorporate, if necessary, one or more solubilizing agent, buffers, preservatives, colorants, perfumes, flavorings and the like that are widely used in the field of pharmaceutical preparation.

[0083] The non-glycosylated apoA-IV or biologically active analogue thereof may be formulated into a dosage form selected from the group consisting of tablets, capsules, granules, pills, injections, solutions, emulsions, suspensions, and syrups. The form and administration route for the pharmaceutical composition are not limited and can be suitably selected. For example, tablets, capsules, granules, pills, syrups, solutions, emulsions, and suspensions may be administered orally. Additionally, injections (e.g. subcutaneous, intravenous, intramuscular, and intraperitoneal) may be administered intravenously either singly or in combination with a conventional replenisher containing glucose, amino acid and/or the like, or may be singly administered intramuscularly, intracutaneously, subcutaneously and/or intraperitoneally.

[0084] The pharmaceutical composition of the invention for treating type 2 diabetes may be prepared according to a method known in the pharmaceutical field of this kind using a pharmaceutically acceptable carrier. For example, oral forms such as tablets, capsules, granules, pills and the like are prepared according to known methods using excipients such as saccharose, lactose, glucose, starch, mannitol and the like; binders such as syrup, gum arabic, sorbitol, tragacanth, methylcellulose, polyvinylpyrrolidone and the like; disintegrates such as starch, carboxymethylcellulose or the calcium salt thereof, microcrystalline cellulose, polyethylene glycol and the like; lubricants such as talc, magnesium stearate, calcium stearate, silica and the like; and wetting agents such as sodium laurate, glycerol and the like.

[0085] Injections, solutions, emulsions, suspensions, syrups and the like may be prepared according to a known method suitably using solvents for dissolving the active ingredient, such as ethyl alcohol, isopropyl alcohol, propylene glycol, 1,3-butylene glycol, polyethylene glycol, sesame oil and the like; surfactants such as sorbitan fatty acid ester, polyoxyethylenesorbitan fatty acid ester, polyoxyethylene fatty acid ester, polyoxyethylene of hydrogenated castor oil, lecithin and the like; suspending agents such as cellulose derivatives including carboxymethylcellulose sodium, methylcellulose and the like, natural gums including tragacanth, gum arabic and the like; and preservatives such as parahydroxybenzoic acid esters, benzalkonium chloride, sorbic acid salts and the like.

[0086] The proportion of the active ingredient to be contained in the pharmaceutical composition of the invention for treating type 2 diabetes can be suitably selected from a wide range.

[0087] In one particular embodiment, the subject in need of treatment of type 2 diabetes is a mammal. The mammal may be selected from the group consisting of humans, non-human primates, canines, felines, murines, bovines, equines, porcines, and lagomorphs. In one specific embodiment, the mammal is human. In another embodiment, non-glycosylated apoA-IV or a biologically active analogue thereof may be administered to a subject for the treatment of type 2 diabetes wherein the subject is obese. Alternatively, non-glycosylated apoA-IV may be administered to a subject for the treatment of type 2 diabetes wherein the subject is not obese.

[0088] Referring to FIG. 1, in yet another embodiment, a device 1 is disclosed. In one embodiment, the device 1 comprises a reservoir 10 of the pharmaceutical composition previously discussed above. In a further embodiment, the reservoir 10 comprises a vial 12. The vial 12 may be formed of any material that does not inhibit the function of the pharmaceutical composition. For example, the vial 12 may comprise glass and/or plastic. Additionally, the vial 12 may comprise a pierceable septum 14 through which the pharmaceutical composition may be removed. In use, the septum 14 of the vial is pierced by the needle 22 of a syringe 20, the pharmaceutical composition is removed by the syringe 20 from the vial 12, and the pharmaceutical composition is administered via injection to a subject in need.

EXAMPLES

[0089] The following non-limiting examples illustrate the methods of the present disclosure.

Example 1: Glucose Intolerance of ApoA-IV Knockout Mice

[0090] *Experimental Protocol.* Male apoA-IV knockout ("hereinafter "KO") mice were obtained. Wild-type (hereinafter "WT") mice served as controls. ApoA-IV KO and WT mice were obtained from a colony kept at the University of Cincinnati (Cincinnati, OH). ApoA-IV KO and WT mice were fed a chow diet. Prior to performing the glucose tolerance tests, ApoA-IV KO mice and WT mice were fasted for five hours. In the glucose tolerance tests, the apoA-IV KO mice and WT mice were injected intraperitoneally with a dose of about 2 mg/g body weight of glucose and plasma glucose was measured at about 0, 15, 30, 60, and 120 minutes following the injection of glucose. The glucose tolerance tests were performed twice, once at three months of age and again at sixteen months of age.

[0091] *Experimental Results.* As shown in FIG. 2, apoA-IV KO mice were glucose intolerant relative to the WT mice. Specifically, FIG. 2 shows that plasma glucose levels in WT mice were lower than plasma glucose levels in apoA-IV KO mice for two hours following intraperitoneal injection with glucose. While not being bound by the theory, the implication of these studies was that apoA-IV is necessary for normal

glucose homeostasis (at least in males). Moreover, as shown in FIG. 3, apoA-IV KO mice demonstrated an increased glucose intolerance when tested at sixteen months of age. Specifically, FIG. 3 shows that plasma glucose levels in apoA-IV KO mice tested at sixteen months of age were higher than the plasma glucose levels in apoA-IV KO tested at three months of age. While not being bound by the theory, the implication of these studies was that glucose tolerance of apoA-IV KO mice worsens with age.

Experiment with Female Wild Type and ApoA-IV Knockout Mice

[0092] Female ApoA-IV wildtype and knockout mice were subjected to the same intraperitoneal glucose tolerance test as was used for the male apoA-IV KO and WT mice, as described earlier in this Example 1. The results are shown in Figure 11. Female apoA-IV $^{-/-}$mice, when challenged intraperitoneally with glucose, have increased plasma glucose levels compared with female WT animals, but there is no statistical significant difference. On the other hand, the males have a significant difference between WT and KO animals.

Example 2: Restoration of Glucose Tolerance in ApoA-IV Knockout Mice

[0093] *Experimental Protocol.* Upon demonstrating that apoA-IV KO mice are glucose intolerant, a series of extensive studies were performed to determine whether administration of apoA-IV to apoA-IV KO mice would restore glucose tolerance to a normal level. Specifically, a series of studies were performed to determine not only the amount of apoA-IV to be administered but also the optimal time in which to administer apoA-IV prior to conducting glucose tolerance tests.

[0094] ApoA-IV male KO mice were injected intraperitoneally with doses of about 0.25, 0.5, 1, and 2 μg/g by weight of apoA-IV. ApoA-IV KO mice were also injected intraperitoneally with saline solution to serve as a control. Following injection with mouse apoA-IV or saline solution, glucose tolerance tests were conducted at three months of age as previously discussed. Specifically, glucose tolerance tests were conducted about two hours following injection with apoA-IV or saline solution. Experimental results indicated that the optimal time to restore glucose tolerance in

apoA-IV KO mice was to administer apoA-IV about two hours prior to conducting glucose tolerance tests.

[0095] *Experimental Results.* As shown in FIG. 4, the administration of apoA-IV to apoA-IV KO mice restored glucose tolerance to a normal level. Specifically, FIG. 4 shows that plasma glucose levels in apoA-IV KO mice injected with apoA-IV were lower than plasma glucose levels in apoA-IV KO mice injected with saline solution. Moreover, as shown in FIG. 4, plasma glucose levels in apoA-IV KO mice injected with apoA-IV were the lowest in the apoA-IV KO mice injected with the highest dosage of apoA-IV; similarly, plasma glucose levels in apoA-IV KO mice injected with apoA-IV were the highest in the apoA-IV KO mice injected with the lowest dosage of apoA-IV. Accordingly, it was discovered that the degree of improvement of glucose tolerance was dependent on the dose of apoA-IV administered, with higher doses resulting in improved glucose tolerance.

Example 3: Specificity of ApoA-IV in Restoring Glucose Tolerance in ApoA-IV Knockout Mice

[0096] *Experimental Protocol.* In order to assess the specificity of apoA-IV, we administered apolipoprotein AI (hereinafter "apoA-I") to apoA-IV KO mice. ApoA-I is a protein made by the small intestinal epithelial cells which also produce apoA-IV. ApoA-I shares many of the functions of apoA-IV. ApoA-IV KO mice were injected intraperitoneally with a dose of 1 μg/g by weight of apoA-I. ApoA-IV KO mice were also injected intraperitoneally with saline solution to serve as a control. Following injection with apoA-I or saline solution, glucose tolerance tests were conducted at three months of age as previously discussed. Specifically, glucose tolerance tests were conducted about two hours following injection with apoA-I or saline solution.

[0097] *Experimental Results.* As shown in FIG. 5, the administration of apoA-I to apoA-IV KO mice failed to restore or improve glucose tolerance.

Example 4: Mechanism of Restoration of Glucose Tolerance in ApoA-IV Knockout Mice

[0098] *Experimental Protocol.* In order to assess the mechanism by which ApoA-IV improves glucose tolerance in apoA-IV KO mice, we measured glucose-induced insulin secretion in apoA-IV KO mice. More specifically, we measured glucose-induced insulin

secretion during glucose tolerance tests at three months of age as previously discussed. In this study, apoA-IV KO mice were injected intraperitoneally with a dose of about 1 μg/g by weight of mouse apoA-IV two hours prior to conducting the glucose tolerance tests. ApoA-IV KO mice were injected with saline solution about two hours prior to conducting glucose tolerance tests to serve as a control.

[0099] *Experimental Results.* As shown in FIG. 6, phase I insulin secretion was absent in apoA-IV KO mice injected with saline solution. However, as shown in FIG. 6, phase I insulin secretion was restored in apoA-IV KO mice when apoA-IV was injected intraperitoneally two hours prior to performing the glucose tolerance tests.

Example 5: Efficacy of ApoA-IV in ApoA-IV Knockout and Wild-Type Mice on High Fat Diets

[00100] *Experimental Protocol.* ApoA-IV KO and WT mice were chronically fed a high-fat semi-purified, nutritionally complete experimental diets (AIN-93M) purchased from Dyets (Bethlehem, PA) for 10 weeks. The high-fat diets contain about 20 g of fat (i.e. about 19 g of butter fat and 1 g of soybean oil to provide essential fatty acids) per 100 g of diet. The apoA-IV KO and WT mice were housed in individual tub cages with corncob bedding in a temperature- (about 22 ± 1° C) and light- (about 12 h light/12 dark) controlled vivarium. Glucose tolerance tests were performed at three months of age as previously discussed. Prior to performing the glucose tolerance tests, apoA-IV KO mice and WT mice were fasted for five hours. In the glucose tolerance tests, the apoA-IV KO mice and WT mice were injected intraperitoneally with a dose of about 2 mg/g body weight of glucose.

[00101] *Experimental Results.* As shown in FIG. 7, apoA-IV KO mice displayed greater glucose intolerance relative to the WT mice. Specifically, FIG. 7 shows that plasma glucose levels in WT mice were lower than plasma glucose levels in apoA-IV KO mice for two hours following intraperitoneal injection with glucose.

Example 6: Restoration of Glucose Tolerance in ApoA-IV Knockout and Wild-Type Mice on High Fat Diets

[00102] *Experimental Protocol.* A series of studies were performed related to the administration of apoA-IV to apoA-IV KO and WT mice on high-fat diets for 14 weeks at three months of age (20% by weight of fat, 19% of butter fat and 1% of safflower oil).

Specifically, apoA-IV KO and WT mice were injected intraperitoneally with a dose of about 1 μg/g body weight of mouse apoA-IV. ApoA-IV KO and WT mice were also injected intraperitoneally with saline solution to serve as a control. Following injection with apoA-IV or saline solution, glucose tolerance tests were conducted. Specifically, glucose tolerance tests were conducted two hours following injection with apoA-IV or saline solution.

[00103] *Experimental Results.* As shown in FIG. 8, the administration of apoA-IV in apoA-IV KO mice significantly improved glucose tolerance. Specifically, FIG. 8 shows that plasma glucose levels in apoA-IV KO mice injected with apoA-IV were lower than plasma glucose levels in apoA-IV KO mice injected with saline solution. [the previous sentence is redundant since the next sentence describes the same thing. Although the data is not included herein, it was also discovered that the administration of apoA-IV in WT mice fed chronically a high fat diet also significantly improved glucose tolerance.

Example 7: Restoration of Glucose Tolerance in Mice with Type 2 Diabetes

[00104] *Experimental Protocol.* In order to confirm that apoA-IV is effective in promoting glucose tolerance in animals with type 2 diabetes, heterozygous KK Cg-A/J (hereinafter "Cg-A/J") mice were obtained from Jackson Laboratories (Bar Harbor, Maine). Cg-A/J mice develop hyperglycemia, hyperinsulinemia, obesity, and glucose intolerance by eight weeks of age. The main cause of diabetes in these mice is insulin resistance produced by the polygenic interactions with the A^y mutation, which encodes the agouti related protein and antagonist of the melanocortin-IV receptor. The Cg-A/J mice were fed chow diet. Additionally, there was a marked increase in blood glucose from ten to fourteen weeks of feeding the chow diet.

[00105] At fourteen weeks of age, the Cg-A/J mice were administered either mouse apoA-IV (about 1 μg/g body weight) or saline solution (to serve as a control) via intraperitoneal injection. Plasma glucose was then determined at about 0, 0.5, 1, 2, 3, 4, 5, 7, 11, and 24 hours.

[00106] *Experimental Results.* As shown in FIG. 9, apoA-IV has a marked effect in lowering the blood sugar level of the Cg-A/J mice relative to the saline control. While the Cg-A/J mice injected with saline solution maintained a steady plasma glucose level throughout the 24 hour period of study, the Cg-A/J mice injected with apoA-IV

experienced a decrease in plasma glucose for over 10 hours, and, during most of this period, the plasma glucose level was comparable to the C57BL/6J animals we have been studying. From this study, we conclude that the administration of apoA-IV is effective in lowering the plasma glucose in Cg-A/J mice.

Example 8: Level of Serum Amyloid P Component in ApoA-IV KO, ApoA-I KO, and WT Mice

[00107] *Experimental Protocol.* A series of studies were performed in related to determining the level of serum amyloid A protein component (hereinafter "SAP") in apoA-IV KO, apoA-I KO, and WT mice on atherogenic diets. The apoA-IV KO, apoA-I KO, and WT mice were obtained from the University of Cincinnati. SAP is a serum form of amyloid P component (hereinafter "AP"), a 25 kDa pentameric protein first identified as the pentagonal constituent of *in vivo* pathological deposits called amyloid. SAP behaves like C-reactive protein in humans. Specifically, the level of plasma SAP in apoA-IV KO, apoA-I KO, and WT mice was determined in apoA-IV KO, apoA-I KO, and WT mice after 12 weeks on an atherogenic diet. The level of plasma SAP was determined via Western blot analysis.

[00108] *Experimental Results.* As shown in FIG. 10, the level of SAP in apoA-IV KO mice (corresponding to mouse numbers 1, 8, and 10) increased relative to the level of SAP in apoA-I KO mice (corresponding to mouse numbers 28, 29, and 30) and WT mice (corresponding to mouse numbers 19, 20, and 25).

[00109] For the purposes of describing and defining the present disclosure it is noted that the terms "about" and "substantially" are utilized herein to represent the inherent degree of uncertainty that may be attributed to any quantitative comparison, value, measurement, or other representation. The terms "about" and "substantially" are also utilized herein to represent the degree by which a quantitative representation may vary from a stated reference without resulting in a change in the basic function of the subject matter at issue.

[00110] The above description and drawings are only to be considered illustrative of exemplary embodiments, which achieve the features and advantages of the present disclosure. Modification and substitutions the features and steps described can be made without departing from the intent and scope of the present disclosure. Accordingly, the

disclosure is not to be considered as being limited by the foregoing description and drawings, but is only limited by the scope of the appended claims.

Example 9: Human ApoA-IV Lowers Blood Glucose Levels in Wild-Type Mice Undergoing Intraperitoneal Glucose Tolerance Testing

[00111] *Experimental Protocol.* Studies were performed to determine whether administration of human apoA-IV to wild type mice would affect blood glucose levels in mice undergoing glucose tolerance testing.

[00112] Three month old wild type mice were injected intraperitoneally with doses of about 1 μg/g by weight of human apoA-IV. As a control, another group of wild type mice was injected intraperitoneally with saline solution. Following injection with human apoA-IV or saline solution, glucose tolerance tests were conducted. Specifically, glucose tolerance tests were conducted about two hours following injection with apoA-IV or saline solution and after five hours of fasting. Tail blood was collected and measure by glucometer.

[00113] *Experimental Results.* As shown in Figure 12, human apoA-IV was effective in lowering blood glucose in wild type mice undergoing glucose tolerance testing.

Example 10. Effect of Mouse ApoA-IV in Wild-Type Female Mice Undergoing Intraperitoneal Glucose Tolerance Testing

[00114] *Experimental Protocol.* Studies were performed to determine whether administration of mouse apoA-IV to female wild type mice would affect blood glucose levels in mice undergoing glucose tolerance testing.

[00115] Three month old female wild type mice were injected intraperitoneally with doses of about 1 μg/g by weight of mouse apoA-IV. As a control, another group of female wild type mice were injected intraperitoneally with saline solution. Following injection with human apoA-IV or saline solution, glucose tolerance tests were conducted. Specifically, glucose tolerance tests were conducted about two hours following injection with apoA-IV or saline solution and after five hours of fasting. Tail blood was collected and measure by glucometer.

Experimental Results. As shown in Figure 13, mouse apoA-IV was effective in lowering blood glucose in wild type female mice undergoing glucose tolerance testing.

Example 11 Human ApoA-IV Stimulates Insulin Release in Human Islets

[00116] High purity human islets were provided by University of Virginia, Axon Cells. Islets were cultured in RPMI 1640, containing 10 % FBS and 11mM glucose at 37° C in a humidified atmosphere of 95 % air and 5% CO_2 for 48 hours. Four Groups of 50 IEQ islets were then pre-incubated at 37° C for 1 h in regular KRB (129mM NaCl, 4.8mM KCl, 2.5mM $CaCl_2$, 1.2 mM $MgSO_4$, 1.2mM KH_2PO_4, 5mM $NaHCO_3$, 10mM HEPES and 0.2% BSA)containing 3.0 mM glucose. Islets in the first two groups were then incubated in regular KRB containing 3.0mM glucose for an hour in the presence or absence of 10µg/ml human A-IV and were further incubated with 20 mM glucose for an additional hour in the presence or absence of 10 µg/ml human A-IV. Islets in the last two groups were incubated in 30mM KCl KRB (103.8 mM NaCl, 30mM KCl, 2.5mM $CaCl_2$, 1.2 mM $MgSO_4$, 1.2mM KH_2PO_4, 5mM $NaHCO_3$, 10mM HEPES and 0.2% BSA) plus 250µmol/l diazoxide containing 3.0mM glucose for an hour in the presence or absence of 10µg/ml human A-IV and were further incubated with 20mM glucose for an additional hour in the presence or absence of 10µg/ml human A-IV. Media were collected at the end of each one-hour incubation. Insulin levels were measured by ELISA kit (Millipore).

[00117] As can be seen from FIG. 14, when the human islets were maximally depolarized by 30mM KCl plus 250µM diazoxide, 10 µg/ml hA-IV showed a significant stimulatory effect on insulin secretion.

Example 12 Preparation of Non-Glycosylated ApoA-IV

[00118] Human and mouse apoA-IV cDNA was contained in a pSP65 maintenance vector, and an *Afl* III restriction site was engineered immediately 5' of the coding sequence for the mature apoA-IV protein. The gene was excised from the maintenance vector and ligated into the pET30 expression vector. The construct was transfected into *E. Coli BL-21* (DE3) cells and grown in Luria- Bertani cultures supplemented with kanamycin (30 µg/ml) at 37℃. After induction of apoA-IV protein synthesis in the cells, the cells were harvested and sonicated. ApoA-IV protein from the lysate was purified by

His-bind affinity column chromatography and dialysis. The resultant apoA-IV protein was diluted to a final concentration of 1.0 mg/ml in saline.

Example 13 Absence of N- and O- Glycosylation in Human ApoA-IV

[00119] Using NetNGlyc 1.0 server at www.cbs.dtu.dk/cgi-bin/webface?jobid=netNglyc, 4F9C6AD203AFBD5C, human apoA-IV and 45 missense variants were analyzed *in silico*. Details regarding the missense variants are provided in Table 1. The O- and N-linked glycosylation analyses are exemplified in Figures 24 and 25 by the native apoA-IV and an exemplary variant, i.e., P393H. The results show that human apoA-IV and the missense variants do not possess any N-linked or N-linked glycosylation sites. Notably, the variants described in Table 1 (represented by the amino acid sequences described in SEQ ID NOs: 20-64; SEQ ID NO 65 represents ApoAIV with the signal sequence) had glycosylation profiles identical to those presented in Figures 24 and 25. These results are unexpected in view of common knowledge in the art, e.g., Weinberg, et al., J Lipid Res. 1983, 24(1):52-9, that apoA-IV is glycosylated by mannose, galactose, N-acetyl glucosamine, and sialic acid.

Table 1. ApoAIV variants (APOA4 gene (mRNA accession no, NM_000482.3))

SNP Pos	rs ID	Alleles	EA Allele #	AA Allele #	All Allele #	Avg. Sample Read Depth	GVS Function	Amino Acid	Protein Pos.	cDNA Pos.
11:11669554	unknown	A/G	A=6/G=7014	A=0/G=3738	A=6/G=10752	51	utr-3	none	NA	NA
11:11669557	unknown	A/G	A=0/G=7020	A=2/G=3736	A=2/G=10756	51	utr-3	none	NA	NA
11:11669562	unknown	A/G	A=1/G=7019	A=0/G=3738	A=1/G=10757	51	utr-3	none	NA	NA
11:11669596	unknown	T/G	T=0/G=7020	T=1/G=3737	T=1/G=10757	46	missense mutation	HIS, PRO	393/397	1178
11:11669610	unknown	T/C	T=2/C=7016	T=0/C=3738	T=2/C=10754	46	silent mutation	none	388/397	1164
11:11669621	rs14087 8274	T/G	T=0/G=7016	T=13/G=3725	T=13/G=10741	47	missense mutation	LYS, GLN	385/397	1153
11:11669628	rs14339 2864	T/C	T=1/C=7015	T=54/C=3684	T=55/C=10699	48	silent mutation	none	382/397	1146
11:11669633	unknown	T/G	T=0/G=7016	T=1/G=3737	T=1/G=10753	49	missense mutation	LYS, GLN	381/397	1141
11:11669634	rs5110	A/C	A=559/C=6457	A=66/C=3672	A=625/C=10129	49	missense mutation	HIS, GLN	380/397	1140
11:11669644	unknown	G/T	G=0/T=7016	G=1/T=3737	G=1/T=10753	52	missense mutation	PRO, GLN	377/397	1130
11:11669645	unknown	A/G	A=1/G=7015	A=0/G=3738	A=1/G=10753	52	stop-gained	stop, GLN	377/397	1129

SNP Pos	rs ID	Alleles	EA Allele #	AA Allele #	All Allele #	Avg. Sample Read Depth	GVS Function	Amino Acid	Protein Pos.	cDNA Pos.
11:11669 1655	unknow n	T/C	T=0/C= 7016	T=1/C=3 737	T=1/C=1 0753	55	silent mutation	none	373/397	1119
11:11669 1675	rs675	A/T	A=1403/ T=5611	A=416/T =3322	A=1819/ T=8933	66	missense mutation	SER, THR	367/397	1099
11:11669 1703	unknow n	A/G	A=1/G= 7011	A=0/G=3 738	A=1/G=1 0749	78	silent mutation	none	357/397	1071
11:11669 1717	rs14635 3487	C/A	C=3/A= 7009	C=96/A= 3642	C=99/A= 10651	83	missense mutation	ALA, SER	353/397	1057
11:11669 1720	rs14757 7451	A/T	A=2/T= 7010	A=1/T=3 737	A=3/T=1 0747	84	missense mutation	TYR, ASN	352/397	1054
11:11669 1754	unknow n	T/C	T=0/C= 7012	T=1/C=3 737	T=1/C=1 0749	78	silent mutation	none	340/397	1020
11:11669 1766	rs5109	A/C	A=1/C= 7011	A=284/C =3454	A=285/C =10465	76	silent mutation	none	336/397	1008
11:11669 1768	rs14576 1354	T/C	T=8/C= 7004	T=1/C=3 737	T=9/C=1 0741	76	missense mutation	MET, VAL	336/397	1006
11:11669 1771	rs14820 3811	G/C	G=1/C= 7011	G=0/C=3 738	G=1/C=1 0749	75	missense mutation	HIS, ASP	335/397	1003
11:11669 1843	unknow n	T/C	T=1/C= 7011	T=0/C=3 738	T=1/C=1 0749	60	missense mutation	ARG, GLY	311/397	931
11:11669 1844	unknow n	A/G	A=2/G= 7010	A=0/G=3 738	A=2/G=1 0748	59	silent mutation	none	310/397	930
11:11669 1855	rs5108	G/C	G=0/C= 7012	G=4/C=3 734	G=4/C=1 0746	53	missense mutation	LEU, VAL	307/397	919
11:11669 1861	rs15026 4487	A/G	A=1/G= 7011	A=0/G=3 738	A=1/G=1 0749	49	missense mutation	CYS, ARG	305/397	913
11:11669 1863	rs15062 4574	T/C	T=1/C= 7011	T=0/C=3 738	T=1/C=1 0749	48	missense mutation	GLN, ARG	304/397	911
11:11669 1886	rs5107	T/C	T=0/C= 7008	T=11/C= 3727	T=11/C= 10735	41	silent mutation	none	296/397	888
11:11669 1902	unknow n	C/T	C=2/T= 6998	C=0/T=3 736	C=2/T=1 0734	40	missense mutation	GLY, GLU	291/397	872
11:11669 1928	rs5106	A/G	A=2/G= 7004	A=148/G =3586	A=150/G =10590	37	silent mutation	none	282/397	846
11:11669 1937	unknow n	G/C	G=1/C= 7011	G=1/C=3 737	G=2/C=1 0748	36	missense mutation	SER, ARG	279/397	837
11:11669 1953	unknow n	G/A	G=0/A= 7010	G=1/A=3 733	G=1/A=1 0743	36	missense mutation	ALA, VAL	274/397	821
11:11669 1954	unknow n	T/C	T=1/C= 7011	T=0/C=3 734	T=1/C=1 0745	36	missense mutation	MET, VAL	274/397	820
11:11669 1955	rs14636 5840	A/G	A=1/G= 7009	A=2/G=3 736	A=3/G=1 0745	36	silent mutation	none	273/397	819
11:11669 1983	rs22380 08	T/C	T=1/C= 7009	T=6/C=3 732	T=7/C=1 0741	46	missense mutation	GLN, ARG	264/397	791
11:11669 1994	rs5105	A/G	A=0/G= 7012	A=67/G= 3671	A=67/G= 10683	50	silent mutation	none	260/397	780
11:11669 1996	rs14422 5488	T/C	T=1/C= 7011	T=0/C=3 738	T=1/C=1 0749	50	missense mutation	THR, ALA	260/397	778
11:11669 2026	rs12190 9576	T/C	T=2/C= 7010	T=0/C=3 738	T=2/C=1 0748	70	missense mutation	LYS, GLU	250/397	748
11:11669 2070	rs14872 4513	C/T	C=0/T= 7012	C=2/T=3 736	C=2/T=1 0748	116	missense mutation	SER, ASN	235/397	704
11:11669 2083	rs14228 3748	T/G	T=0/G= 7012	T=1/G=3 737	T=1/G=1 0749	127	missense mutation	LYS, GLN	231/397	691
11:11669 2116	unknow n	A/G	A=0/G= 7012	A=1/G=3 737	A=1/G=1 0749	160	missense mutation	CYS, ARG	220/397	658
11:11669 2120	rs15121 2572	T/C	T=0/C= 7012	T=1/C=3 737	T=1/C=1 0749	169	silent mutation	none	218/397	654
11:11669 2132	unknow n	G/C	G=0/C= 7012	G=1/C=3 737	G=1/C=1 0749	189	missense mutation	HIS, GLN	214/397	642
11:11669 2153	rs13920 4483	C/T	C=0/T= 7014	C=1/T=3 737	C=1/T=1 0751	227	silent mutation	none	207/397	621
11:11669 2155	rs14518 4607	T/C	T=1/C= 7015	T=0/C=3 738	T=1/C=1 0753	230	missense mutation	LYS, GLU	207/397	619

SNP Pos	rs ID	Alleles	EA Allele #	AA Allele #	All Allele #	Avg. Sample Read Depth	GVS Function	Amino Acid	Protein Pos.	cDNA Pos.
11:11669 2169	rs14762 6624	A/G	A=1/G= 7019	A=1/G=3 737	A=2/G=1 0756	245	missense mutation	MET, THR	202/397	605
11:11669 2176	rs14205 0734	A/G	A=1/G= 7019	A=0/G=3 738	A=1/G=1 0757	251	missense mutation	CYS, ARG	200/397	598
11:11669 2195	unknow n	A/G	A=0/G= 7020	A=1/G=3 737	A=1/G=1 0757	239	silent mutation	none	193/397	579
11:11669 2203	rs14589 8188	T/C	T=1/C= 7019	T=0/C=3 738	T=1/C=1 0757	228	missense mutation	ASN, ASP	191/397	571
11:11669 2204	rs14552 5856	T/G	T=0/G= 7020	T=9/G=3 729	T=9/G=1 0749	225	silent mutation	none	190/397	570
11:11669 2224	rs14881 5297	T/C	T=0/C= 7020	T=1/C=3 737	T=1/C=1 0757	185	missense mutation	ASN, ASP	184/397	550
11:11669 2232	unknow n	A/G	A=1/G= 7019	A=0/G=3 738	A=1/G=1 0757	166	missense mutation	LEU, PRO	181/397	542
11:11669 2240	unknow n	T/C	T=1/C= 7019	T=0/C=3 738	T=1/C=1 0757	150	silent mutation	none	178/397	534
11:11669 2258	rs14345 1944	C/G	C=1/G= 7019	C=0/G=3 738	C=1/G=1 0757	112	silent mutation	none	172/397	516
11:11669 2260	rs14836 4897	T/C	T=1/C= 7019	T=0/C=3 738	T=1/C=1 0757	107	missense mutation	THR, ALA	172/397	514
11:11669 2269	rs14229 5954	A/G	A=0/G= 7020	A=1/G=3 737	A=1/G=1 0757	92	missense mutation	TRP, ARG	169/397	505
11:11669 2277	rs14578 6821	T/C	T=1/C= 7019	T=0/C=3 738	T=1/C=1 0757	83	missense mutation	LYS, ARG	166/397	497
11:11669 2291	unknow n	C/T	C=1/T= 7017	C=0/T=3 738	C=1/T=1 0755	65	silent mutation	none	161/397	483
11:11669 2293	rs12721 043	A/C	A=77/C =6941	A=9/C=3 729	A=86/C= 10670	62	missense mutation	SER, ALA	161/397	481
11:11669 2294	unknow n	A/G	A=1/G= 7017	A=0/G=3 738	A=1/G=1 0755	61	silent mutation	none	160/397	480
11:11669 2312	rs14283 5053	T/C	T=2/C= 7016	T=0/C=3 736	T=2/C=1 0752	46	silent mutation	none	154/397	462
11:11669 2314	rs15063 3651	A/G	A=2/G= 7016	A=0/G=3 736	A=2/G=1 0752	45	missense mutation	TRP, ARG	154/397	460
11:11669 2324	rs22346 68	A/G	A=358/ G=6660	A=37/G= 3699	A=395/G =10359	40	silent mutation	none	150/397	450
11:11669 2331	rs14933 9479	A/G	A=1/G= 7015	A=0/G=3 738	A=1/G=1 0753	39	missense mutation	MET, THR	148/397	443
11:11669 2334	rs5104	T/C	T=6133/ C=885	T=3299/ C=439	T=9432/ C=1324	38	missense mutation	ASN, SER	147/397	440
11:11669 2358	rs13976 2470	T/G	T=0/G= 7012	T=1/G=3 737	T=1/G=1 0749	34	missense mutation	GLU, ALA	139/397	416
11:11669 2360	rs14531 7065	A/G	A=0/G= 7014	A=1/G=3 737	A=1/G=1 0751	34	silent mutation	none	138/397	414
11:11669 2393	rs14761 0191	T/G	T=27/G =6971	T=0/G=3 732	T=27/G= 10703	34	missense mutation	LYS, ASN	127/397	381
11:11669 2449	rs64134 56	A/G	A=1/G= 7013	A=3/G=3 731	A=4/G=1 0744	33	silent mutation	none	109/397	325
11:11669 2490	rs14217 6503	A/G	A=0/G= 7018	A=2/G=3 736	A=2/G=1 0754	48	missense mutation	LEU, SER	95/397	284
11:11669 2506	unknow n	A/G	A=0/G= 7016	A=1/G=3 737	A=1/G=1 0753	64	missense mutation	CYS, ARG	90/397	268
11:11669 2521	rs15115 9258	C/T	C=0/T= 7016	C=2/T=3 736	C=2/T=1 0752	78	missense mutation	ALA, THR	85/397	253
11:11669 2543	rs12721 042	A/C	A=0/C= 7018	A=1/C=3 737	A=1/C=1 0755	101	missense mutation	HIS, GLN	77/397	231
11:11669 2552	rs5103	G/A	G=251/ A=6767	G=26/A= 3712	G=277/A =10479	116	silent mutation	none	74/397	222
11:11669 2554	rs5102	T/C	T=0/C= 7018	T=5/C=3 733	T=5/C=1 0751	120	missense mutation	SER, GLY	74/397	220
11:11669 2558	rs5101	A/G	A=7/G= 7013	A=1001/ G=2737	A=1008/ G=9750	129	silent mutation	none	72/397	216

SNP Pos	rs ID	Alleles	EA Allele #	AA Allele #	All Allele #	Avg. Sample Read Depth	GVS Function	Amino Acid	Protein Pos.	cDNA Pos.
11:11669 2594	rs14070 8655	T/G	T=1/G= 7019	T=0/G=3 738	T=1/G=1 0757	199	silent mutation	none	60/397	180
11:11669 2600	unknow n	A/G	A=1/G= 7019	A=0/G=3 738	A=1/G=1 0757	207	intron	none	NA	NA
11:11669 2625	unknow n	A/G	A=1/G= 7017	A=0/G=3 738	A=1/G=1 0755	219	intron	none	NA	NA
11:11669 2634	unknow n	A/G	A=0/G= 7020	A=48/G= 3690	A=48/G= 10710	206	intron	none	NA	NA
11:11669 2645	unknow n	A/G	A=0/G= 7020	A=1/G=3 737	A=1/G=1 0757	186	intron	none	NA	NA
11:11669 3353	rs22390 13	T/C	T=423/ C=6597	T=175/C =3563	T=598/C =10160	257	intron	none	NA	NA
11:11669 3354	rs5093	A/G	A=171/ G=6849	A=91/G= 3647	A=262/G =10496	261	intron	none	NA	NA
11:11669 3377	unknow n	C/G	C=0/G= 7020	C=1/G=3 737	C=1/G=1 0757	281	silent mutation	none	58/397	174
11:11669 3398	rs14591 1376	C/T	C=1/T= 7019	C=0/T=3 738	C=1/T=1 0757	261	silent mutation	none	51/397	153
11:11669 3416	rs13849 0533	A/G	A=0/G= 7020	A=2/G=3 736	A=2/G=1 0756	229	silent mutation	none	45/397	135
11:11669 3464	rs5092	T/C	T=5880/ C=1140	T=3179/ C=559	T=9059/ C=1699	127	silent mutation	none	29/397	87
11:11669 3536	unknow n	A/G	A=1/G= 7019	A=0/G=3 738	A=1/G=1 0757	37	intron	none	NA	NA
11:11669 3871	rs12721 041	T/C	T=125/ C=6887	T=14/C= 3724	T=139/C =10611	160	missense mutation	MET, VAL	13/397	37
11:11669 3875	unknow n	A/G	A=1/G= 7011	A=0/G=3 738	A=1/G=1 0749	162	silent mutation	none	11/397	33
11:11669 3892	rs14831 2574	T/C	T=5/C= 7007	T=2/C=3 736	T=7/C=1 0743	168	missense mutation	MET, VAL	6/397	16
11:11669 3893	unknow n	A/G	A=1/G= 7011	A=0/G=3 738	A=1/G=1 0749	167	silent mutation	none	5/397	15

Note: the filter status is pass for all entries of Table 1.

Example 14 Optimization of ApoA-IV for Bacterial Expression

[00120] To facilitate periplasmic expression of apoA-IV in *E. coli*, constructs were prespared using various signal peptides. These signal peptides (*i.e.* OmpA, PelB, and ENX) were each fused to the N-terminal of apoA-IV. The amino acid and nucleic acid sequences of each these signal sequences are provided as follows:

[00121] OmpA signal peptide

M K K T A I A I A V A L A G F T A V A Q A (SEQ ID NO: 6)

ATG AAA AAG ACA GCT ATC GCG ATT GCA GTG GCA CTG GCT GGT TTC GCT ACC GTA GCG CAG GCC (SEQ ID NO: 7)

PelB signal peptide

M K Y L L P T A A A G L L L L A A Q P A M A (SEQ ID NO: 8)

ATG AAA TAC CTG CTG CCG ACC GCT GCT GCT GGT CTG CTG CTC CTC GCT GCC CAG CCG GCG ATG GCC (SEQ ID NO: 9)

ENX signal peptide

M F K F K K N F L V G L S A A L M S I S L F S A T A S A (SEQ ID NO: 10)

ATG TTT AAG TTT AAA AAG AAT TTC TTA GTT GGA TTA TCG GCA GCT TTA ATG AGT ATT AGC TTG TTT TCG GCA ACC GCC TCT GCA (SEQ ID NO: 11)

[00122] To improve protein yield in *E. coli*, the codon usage for apoA-IV was optimized. Optimization was performed using DNA2.0's algorithm (DNA2.0 Inc.) or other algorithms based on experimental data and the tRNA chargeability (amino acetylation). The apoA-IV coding sequence with optimized codons was then fused at the 5' end to the 3' end of the nucleotide sequence of a signal peptide. In addition, the codon-optimized sequence can be linked at its 3' end to a double stop codon. Constructs with the optimized codons and cloning sites are exemplified in Figures 20-23. The optimized DNA sequences are described in SEQ ID NOs: 13, 15, 17, and 19, with the resulting amino acid sequences set forth in SEQ ID NOs: 12, 14, 16, and 18, respectively. Notably, the optimized sequences (SEQ ID NOs: 12-19) may also be used in the methods and compositions of the invention.

[00123] The apoA-IV- constructs can then be synthesized by DNA2.0, Inc. and sub-cloned into a pJexpress vector (e.g., pJexpress401) using *NdeI-XhoI* restriction sites. These constructs can be transformed into BL21 *E. coli* strain (Novagen) (F^- *OmpT* $hsdS_B(r_B^-m_B^-)$ *gal dcm*) and clones containing these constructs can be selected with Kanamycin. A pre-culture in 125 ml of YES medium containing Kanamycin (e.g., 50 µg/ml) can be inoculated starting from one isolated colony and incubated at 37 °C with agitation at 270 rpm for about 16 hours. A fresh culture in 500 ml of Kanamycin-containing YES medium can be inoculated with 10 mL of the pre-culture and incubated at 37 °C with agitation at 270 rpm until the OD_{600} reaches 0.5 to 1.0 (optimum = 0.6). The resultant culture will then be induced with IPTG (e.g., with a final concentration of 1 mM) and incubated at 37 °C for 1 hour, 2 hours, 4 hours, or 22 hours.

[00124] ApoA-IV protein can be isolated from periplasmic and cytoplasmic fractions of the culture prepared above. More specifically, the culture can be pelleted. The resultant culture pellet can be suspended in hypertonic TES buffer (sucrose 20%) / OD_{600} / mL

and incubated for 5 min at room temperature before dilution in 4 volumes of purified water at 4°C. The diluted suspension can be further incubated for 10 min on ice and centrifuged for 5 min at 13,000 rpm. The resultant supernatant is periplasmic fraction (P) and the pellet is the cytoplasmic fraction. Expression of apoA-IV can be analyzed by SDS-PAGE or Western analysis. ApoA-IV in these fractions can then be purified by conventional and/or affinity chromatography, and formulated for delivery to humans for treatment of type II diabetes.

Incorporation by Reference

The contents of all references and patents cited herein are hereby incorporated by reference in their entirety.

Equivalents

Those skilled in the art will recognize, or be able to ascertain using no more than routine experimentation, many equivalents to the specific embodiments of the invention described herein. Such equivalents are intended to be encompassed by the following claims.

What is claimed is:

1. A method of treating type 2 diabetes in a subject in need thereof, the method comprising administering to the subject an effective amount of a non-glycosylated apolipoprotein A-IV protein, or a biologically active analogue or fragment thereof having at least 90% identity to the apolipoprotein A-IV protein, such that type II diabetes mellitus is treated in the subject, wherein the apolipoprotein A-IV protein, or the biologically active analogue or fragment thereof, is produced using a protein expression system.

2. A method of lowering blood glucose level in a subject in need thereof, the method comprising administering to the subject an effective amount of a non-glycosylated apolipoprotein A-IV protein, or a biologically active analogue or fragment thereof having at least 90% identity to the apolipoprotein A-IV protein, such that the blood glucose level of the subject is lowered, wherein the apolipoprotein A-IV protein, or the biologically active analogue or fragment thereof, is produced using a using a protein expression system.

3. A method for substantially restoring glucose tolerance in a subject in need thereof to a normal level, the method comprising administering to the subject an effective amount of a non-glycosylated apolipoprotein A-IV protein, or a biologically active analogue or fragment thereof, having at least 90% identity to the apolipoprotein A-IV protein, such that glucose tolerance the subject is restored, wherein the apolipoprotein A-IV protein, or the biologically active analogue or fragment thereof, is produced using a protein expression system.

4. The method of any one of Claims 1-3, wherein the non-glycosylated apolipoprotein A-IV protein has at least 95% identity to the apolipoprotein A-IV protein.

5. The method of any one of Claims 1-3, wherein the non-glycosylated apolipoprotein A-IV protein has at least 99% identity to the apolipoprotein A-IV protein.

6. The method of any one of Claims 1-5, wherein the subject is a human.

7. The method of any one of Claims 1-6, wherein the amino acid sequence of the apolipoprotein A-IV protein is

X_1EVSADQVATVMWDYFSQLSNNAKEAVEHLQKSELTQQLNALFQDKL GEVNTYAGDLQKKLVPFATELHERLAKDSEKLKEEIGKELEELRARLLPHANEV SQKIGDNLRELQQRLEPYADQLRTQVNTQAEQLRRQLTPYAQRMERVLRENAD SLQASLRPHADX$_2$LKAKIDQNVEELKGRLTPYADEFKVKIDQTVEELRRSLAPYA QDTQEKLNHQLEGLTFQMKKNAEELKARISASAEELRQRLAPLAEDVRGNLRG NTEGLQKSLAELGGHLDQQVEEFRRRVEPYGENFNKALVQQMEQLRQKLGPH AGDVEGHLSFLEKDLRDKVNSFFSTFKEKESQDKX$_3$L*S*LPELEQQQEQX$_4$QEQQQ EQVQMLAPLES (SEQ ID NO. 4)

wherein, X_1 is G, A, V or absent;

X_2 is E or K;

X_3 is T or S; and

X_4 is Q or H,

or a biologically active analogue or fragment thereof.

8. The method of any one of Claims 1-6, wherein the apolipoprotein A-IV protein is a full length human apolipoprotein A-IV protein.

9. The method of any one of Claims 1-6, wherein the amino acid of the apolipoprotein A-IV protein is

EVSADQVATVMWDYFSQLSNNAKEAVEHLQKSELTQQLNALFQDKLGEVNTY AGDLQKKLVPFATELHERLAKDSEKLKEEIGKELEELRARLLPHANEVSQKIGD NLRELQQRLEPYADQLRTQVNTQAEQLRRQLTPYAQRMERVLRENADSLQASL RPHADELKAKIDQNVEELKGRLTPYADEFKVKIDQTVEELRRSLAPYAQDTQEK LNHQLEGLTFQMKKNAEELKARISASAEELRQRLAPLAEDVRGNLRGNTEGLQ KSLAELGGHLDQQVEEFRRRVEPYGENFNKALVQQMEQLRQKLGPHAGDVEG HLSFLEKDLRDKVNSFFSTFKEKESQDKTL*S*LPELEQQQEQQ*Q*EQQQEQVQMLA PLES (SEQ ID NO. 1), or a biologically active analogue or fragment thereof.

10. The method of any one of Claims 1-6, wherein the amino acid sequence of the apolipoprotein A-IV protein is

GEVSADQVATVMWDYFSQLSNNAKEAVEHLQKSELTQQLNALFQDKL GEVNTYAGDLQKKLVPFATELHERLAKDSEKLKEEIGKELEELRARLLPHANEV SQKIGDNLRELQQRLEPYADQLRTQVNTQAEQLRRQLTPYAQRMERVLRENAD SLQASLRPHADELKAKIDQNVEELKGRLTPYADEFKVKIDQTVEELRRSLAPYA QDTQEKLNHQLEGLTFQMKKNAEELKARISASAEELRQRLAPLAEDVRGNLRG NTEGLQKSLAELGGHLDQQVEEFRRRVEPYGENFNKALVQQMEQLRQKLGPH AGDVEGHLSFLEKDLRDKVNSFFSTFKEKESQDKTLSLPELEQQQEQQQEQQQE QVQMLAPLES (SEQ ID NO. 3), or a biologically active analogue or fragment thereof.

11. The method of any one of Claims 1-10, wherein the using a protein expression system is a bacterial expression system.

12. The method of Claim 11, wherein the bacterial expression system is *Escherichia coli.*

13. The method of any one of Claims 1-10, wherein the protein expression system. is selected from the group consisting of a mammalian expression system, a yeast expression system, a baculovirus expression system, and a cell-free expression system.

14. A method of treating type 2 diabetes in a subject having type 2 diabetes comprising administering to the subject a recombinant, non-glycosylated apoA-IV protein, wherein the apoA-IV protein comprises an amino acid sequence set forth in any one of SEQ ID NOs: 1, 3, 4 or 20-64, or an amino acid sequence having at least 95% identity to any one of SEQ ID NO: 1, 3, 4, or 20-64, or a biologically active fragment thereof.

15. The method of claim 14, wherein the apoA-IV protein comprises an amino acid sequence set forth in any one of SEQ ID NOs: 1, 3, 4 or 20-64, or an amino acid sequence having at least 96% identity to any one of SEQ ID NO: 1, 3, 4, or 20-64, or a biologically active fragment thereof.

16. The method of claim 14, wherein the apoA-IV protein comprises an amino acid sequence set forth in any one of SEQ ID NOs: 1, 3, 4 or 20-64, or an amino acid

sequence having at least 97% identity to any one of SEQ ID NO: 1, 3, 4, or 20-64, or a biologically active fragment thereof.

17. The method of claim 14, wherein the apoA-IV protein comprises an amino acid sequence set forth in any one of SEQ ID NOs: 1, 3, 4 or 20-64, or an amino acid sequence having at least 98% identity to any one of SEQ ID NO: 1, 3, 4, or 20-64, or a biologically active fragment thereof.

18. The method according to any one of Claims 1-17, wherein the apolipoprotein A-IV protein is administered systemically.

19. The method according to Claim 18, wherein the systemic administration of apolipoprotein A-IV protein, or biologically active analogue or fragment thereof, is selected from the group consisting of oral, subcutaneous, intravenous, intramuscular, and intraperitoneal administration.

20. The method according to any one of Claims 1-19, wherein the apolipoprotein A-IV protein, or biologically active analogue or fragment thereof, is administered in a dose of about 1 to about 10 μg/g.

21. The method according to any one of Claims 1-19, wherein the apolipoprotein A-IV protein, or biologically active analogue or fragment thereof, is administered in a dose of about 0.25 to about 2 μg/g .

22. The method according to any one of Claims 1-19, wherein the apolipoprotein A-IV protein, or biologically active analogue or fragment thereof, is administered in a dose of about 1 μg/g.

23. The method according to any one of Claims 1-22, wherein the apolipoprotein A-IV protein, or biologically active analogue or fragment thereof is administered once daily.

24. The method according to any one of Claim 1-22, wherein of apolipoprotein A-IV protein, or biologically active analogue or fragment thereof, is administered about 2 times per day.

25. A pharmaceutical composition comprising non-glycosylated apolipoprotein A-IV protein, or a biologically active analogue or fragment thereof, having at least 90% identity to the apolipoprotein A-IV protein, wherein the apolipoprotein A-IV protein, or the biologically active analogue or fragment thereof, is produced using a protein expression system.

26. A pharmaceutical composition comprising non-glycosylated apolipoprotein A-IV protein comprising an amino acid sequence as set forth in any one of SEQ ID NOs: 1, 3, 4, or 20-64, or an amino acid sequence which is at least 95% identical to any one of SEQ ID NOs: 1, 3, 4, or 20-64, or a biologically active fragment thereof.

27. The pharmaceutical composition of claim 26, wherein the apolipoprotein A-IV protein comprises an amino acid sequence which is at least 96% identical to any one of SEQ ID NOs: 1, 3, 4, or 20-64, or a biologically active fragment thereof.

28. The pharmaceutical composition of claim 26, wherein the apolipoprotein A-IV protein comprises an amino acid sequence which is at least 97% identical to any one of SEQ ID NOs: 1, 3, 4, or 20-64, or a biologically active fragment thereof.

29. The pharmaceutical composition of claim 26, wherein the apolipoprotein A-IV protein comprises an amino acid sequence which is at least 98% identical to any one of SEQ ID NOs: 1, 3, 4, or 20-64, or a biologically active fragment thereof.

30. The pharmaceutical composition of claim 26, wherein the apolipoprotein A-IV protein comprises an amino acid sequence which is at least 99% identical to any one of SEQ ID NOs: 1, 3, 4, or 20-64, or a biologically active fragment thereof.

31. The pharmaceutical composition of any one of claims 25-30, further comprising a pharmaceutically acceptable carrier or diluent.

32. The pharmaceutical composition of any one of claims 25-31, wherein the pharmaceutical composition is selected from the group consisting of a liquid formulation, an aqueous formulation, and a lyophilized formulation.

33. The pharmaceutical composition of any one of claims 25-31, wherein the amino acid sequence of the apolipoprotein A-IV protein is

X_1EVSADQVATVMWDYFSQLSNNAKEAVEHLQKSELTQQLNALFQDKL GEVNTYAGDLQKKLVPFATELHERLAKDSEKLKEEIGKELEELRARLLPHANEV SQKIGDNLRELQQRLEPYADQLRTQVNTQAEQLRRQLTPYAQRMERVLRENAD SLQASLRPHADX$_2$LKAKIDQNVEELKGRLTPYADEFKVKIDQTVEELRRSLAPYA QDTQEKLNHQLEGLTFQMKKNAEELKARISASAEELRQRLAPLAEDVRGNLRG NTEGLQKSLAELGGHLDQQVEEFRRRVEPYGENFNKALVQQMEQLRQKLGPH AGDVEGHLSFLEKDLRDKVNSFFSTFKEKESQDKX$_3$L*S*LPELEQQQEQX$_4$QEQQQ EQVQMLAPLES (SEQ ID NO. 4)

wherein, X_1 is G, A, V or absent;

X_2 is E or K;

X_3 is T or S; and

X_4 is Q or H,

or a biologically active fragment thereof.

34 The pharmaceutical composition of any one of claims 25-31, wherein the apolipoprotein A-IV protein is a full length human apolipoprotein A-IV protein.

35. The pharmaceutical composition of any one of claims 25-31, wherein the amino acid of the apolipoprotein A-IV protein is
EVSADQVATVMWDYFSQLSNNAKEAVEHLQKSELTQQLNALFQDKLGEVNTY AGDLQKKLVPFATELHERLAKDSEKLKEEIGKELEELRARLLPHANEVSQKIGD NLRELQQRLEPYADQLRTQVNTQAEQLRRQLTPYAQRMERVLRENADSLQASL RPHADELKAKIDQNVEELKGRLTPYADEFKVKIDQTVEELRRSLAPYAQDTQEK LNHQLEGLTFQMKKNAEELKARISASAEELRQRLAPLAEDVRGNLRGNTEGLQ KSLAELGGHLDQQVEEFRRRVEPYGENFNKALVQQMEQLRQKLGPHAGDVEG HLSFLEKDLRDKVNSFFSTFKEKESQDKTL*S*LPELEQQQEQQ*Q*EQQQEQVQMLA PLES (SEQ ID NO. 1), or a biologically active fragment thereof.

36. The pharmaceutical composition of any one of claims 25-31, wherein the amino acid sequence of the apolipoprotein A-IV protein is

GEVSADQVATVMWDYFSQLSNNAKEAVEHLQKSELTQQLNALFQDKL GEVNTYAGDLQKKLVPFATELHERLAKDSEKLKEEIGKELEELRARLLPHANEV SQKIGDNLRELQQRLEPYADQLRTQVNTQAEQLRRQLTPYAQRMERVLRENAD SLQASLRPHADELKAKIDQNVEELKGRLTPYADEFKVKIDQTVEELRRSLAPYA QDTQEKLNHQLEGLTFQMKKNAEELKARISASAEELRQRLAPLAEDVRGNLRG NTEGLQKSLAELGGHLDQQVEEFRRRVEPYGENFNKALVQQMEQLRQKLGPH AGDVEGHLSFLEKDLRDKVNSFFSTFKEKESQDKTLSLPELEQQQEQQQEQQQE QVQMLAPLES (SEQ ID NO. 3), or a biologically active fragment thereof.

37. The pharmaceutical composition of any one of claims 25-31, wherein the apolipoprotein A-IV is produced using a protein expression system which is a bacterial expression system.

38. The pharmaceutical composition of claim 37, wherein the bacterial expression system is *Escherichia coli.*

39. The pharmaceutical composition of any one of claims 22-31, wherein the apolipoprotein A-IV is produced using a protein expression system which is selected from the group consisting of a mammalian expression system, a yeast expression system, a baculovirus expression system, and a cell-free expression system.

40. A method of treating type 2 diabetes in a subject in need thereof, said method comprising

producing apolipoprotein A-IV protein, or a biologically active analogue or fragment thereof, in a protein expression system, and

administering the apolipoprotein A-IV protein, or the biologically active analogue or fragment thereof, to a subject having type 2 diabetes,

such that type 2 diabetes is treated, wherein the apolipoprotein A-IV protein, or a biologically active analogue or fragment thereof, is non-glycosylated.

41. The method of claim 40, wherein the protein expression system is a bacterial expression system.

42. The method of claim 40, wherein the protein expression system is a yeast or mammalian cell expression system.

43. The method of any one of claims 40-42, wherein the apolipoprotein A-IV protein comprises an amino acid sequence as set forth in SEQ ID NO: 1, 3, 4 or 20-64, or a biologically active fragment thereof.

44. The method of any one of claims 40-42, wherein the apolipoprotein A-IV protein comprises an amino acid sequence which is at least 95% identical to a sequence as set forth in any one of SEQ ID NO: 1, 3, 4 or 20-64, or a biologically active fragment thereof.

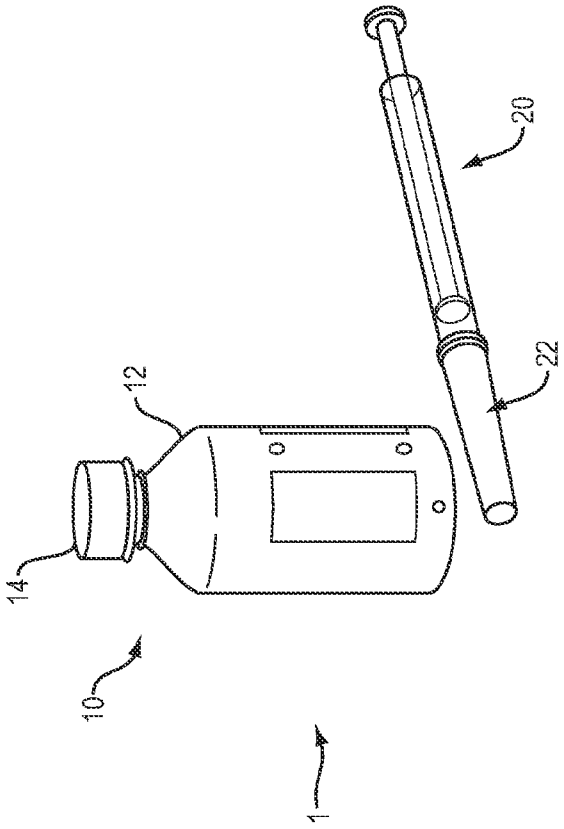


FIG. 1

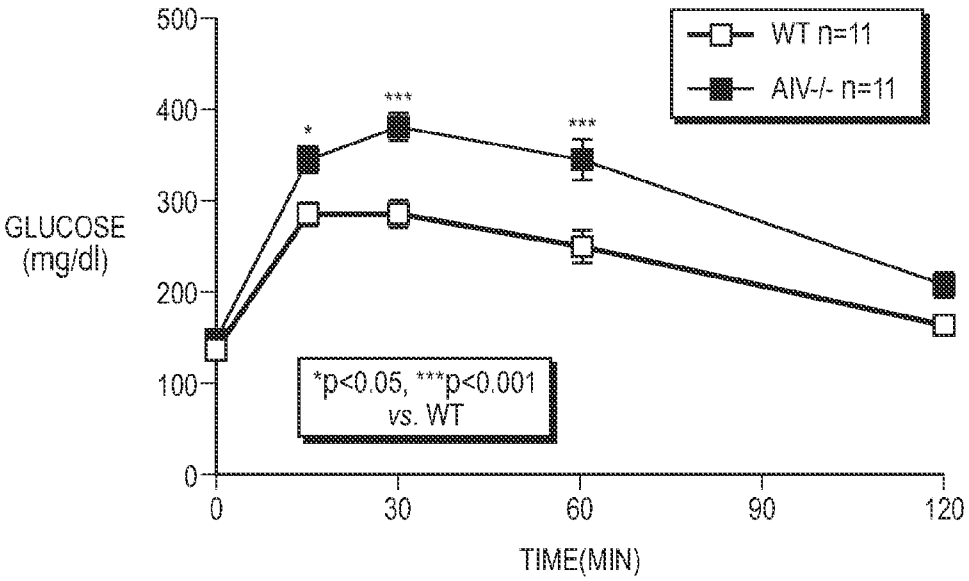

500
400
300
200
100
0
GLUCOSE
(mg/dl)
WT n=11
AIV-/- n=11
*
***
***
*p<0.05, ***p<0.001
vs. WT
0
30
60
90
120
TIME(MIN)

FIG. 2

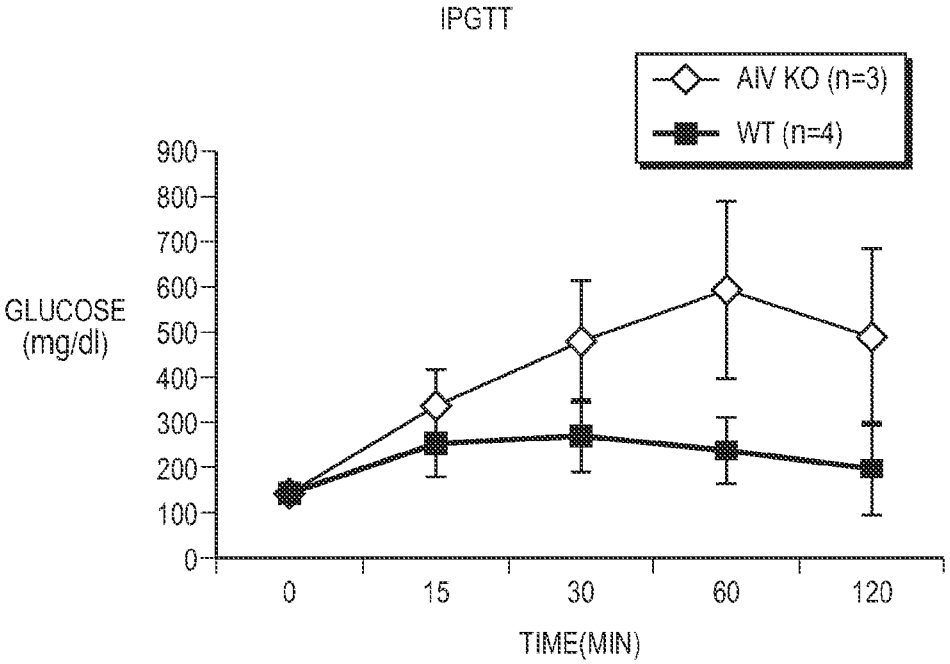

IPGTT
AIV KO (n=3)
WT (n=4)
900
800
700
600
500
400
300
200
100
0
GLUCOSE
(mg/dl)
0
15
30
60
120
TIME(MIN)

FIG. 3

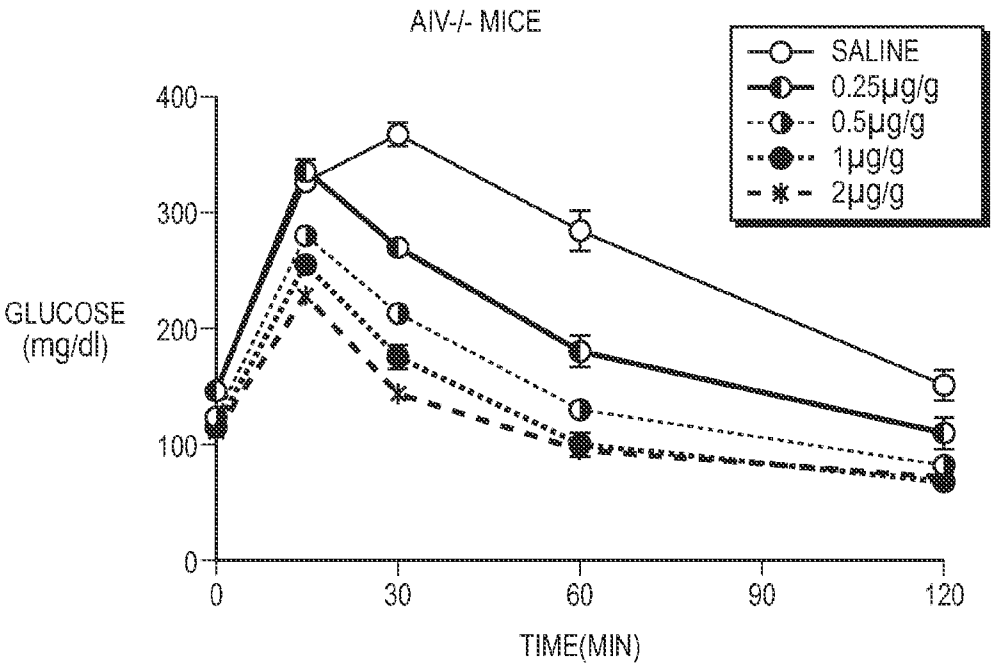

AIV-/- MICE
SALINE
0.25µg/g
0.5µg/g
1µg/g
2µg/g
GLUCOSE (mg/dl)
400
300
200
100
0
0
30
60
90
120
TIME(MIN)

FIG. 4

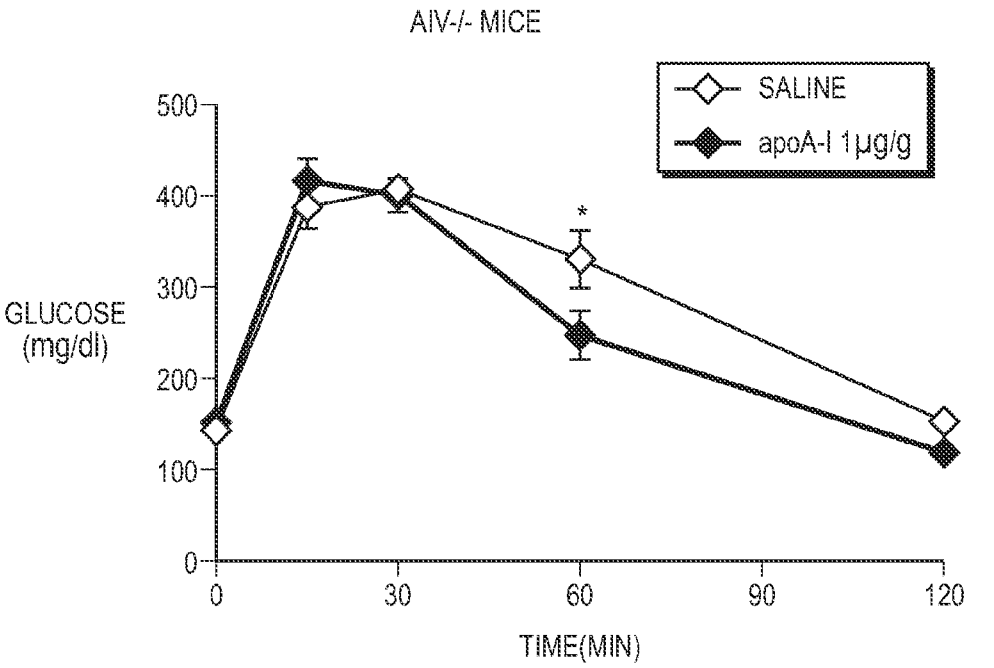

AIV-/- MICE
SALINE
apoA-I 1µg/g
*
GLUCOSE (mg/dl)
500
400
300
200
100
0
0
30
60
90
120
TIME(MIN)

FIG. 5

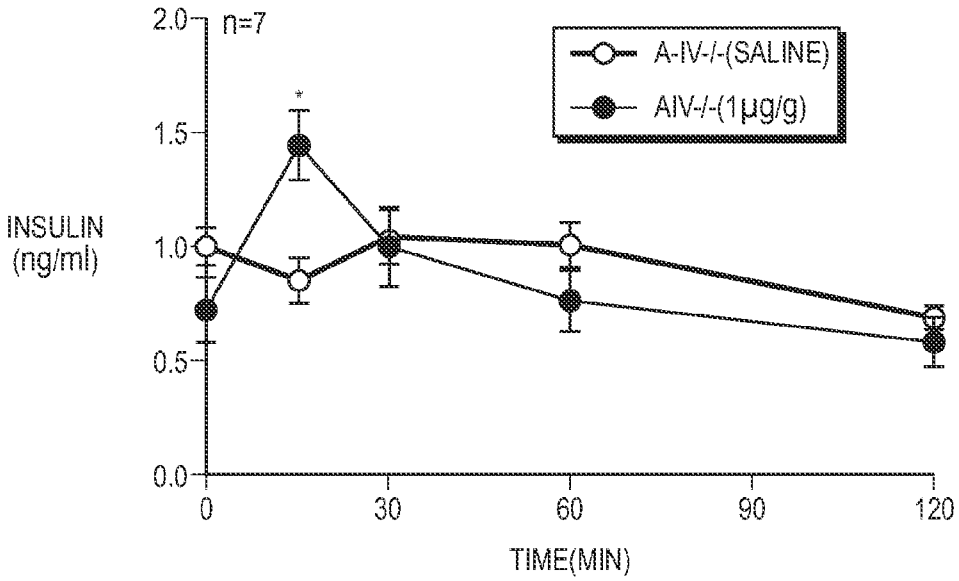

2.0
n=7
1.5
1.0
0.5
0.0
INSULIN
(ng/ml)
*
A-IV-/-(SALINE)
AIV-/-(1µg/g)
0
30
60
90
120
TIME(MIN)

FIG. 6

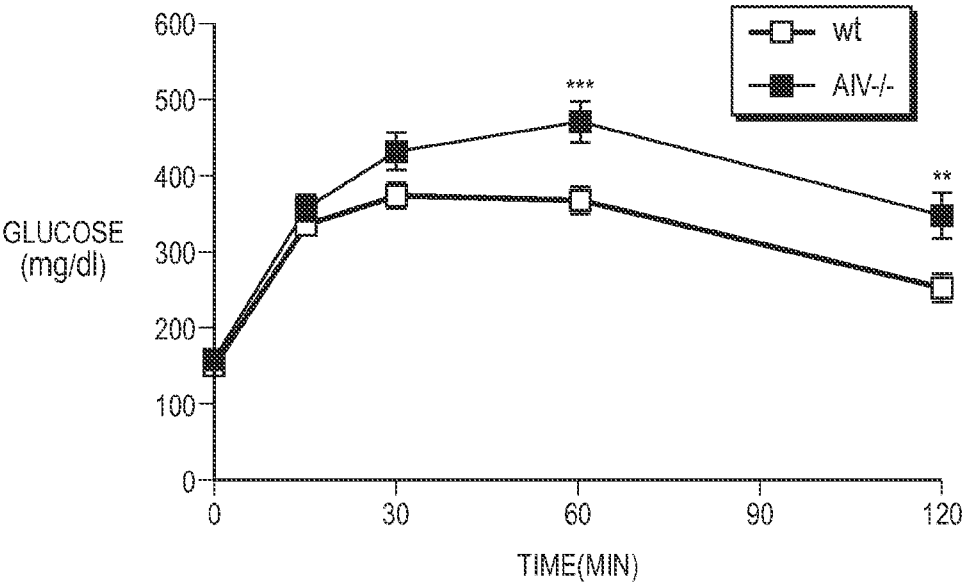

600
500
400
300
200
100
0
GLUCOSE
(mg/dl)
***
**
wt
AIV-/-
0
30
60
90
120
TIME(MIN)

FIG. 7

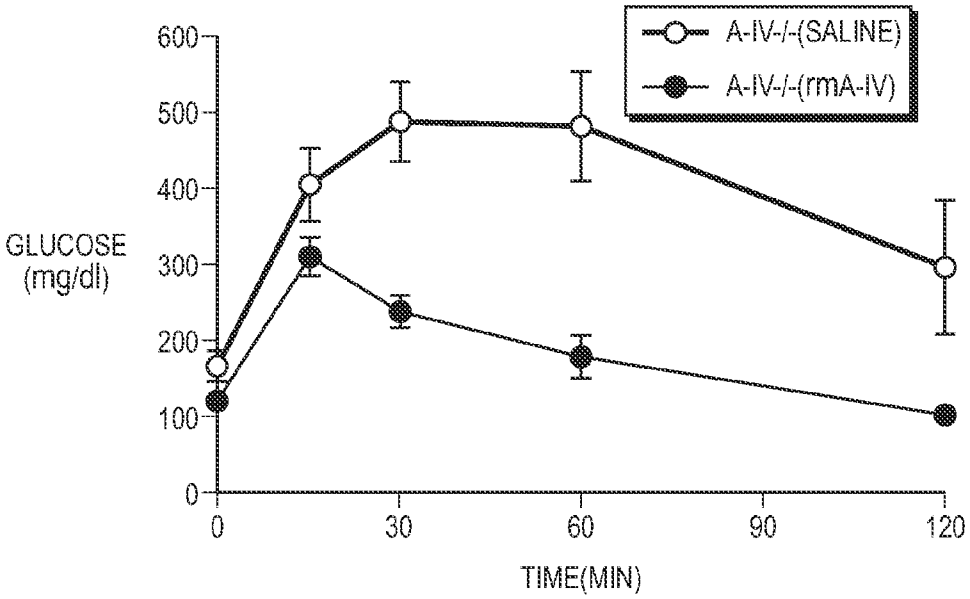

A-IV-/-(SALINE)
A-IV-/-(rmA-IV)
GLUCOSE
(mg/dl)
600
500
400
300
200
100
0
0
30
60
90
120
TIME(MIN)

FIG. 8

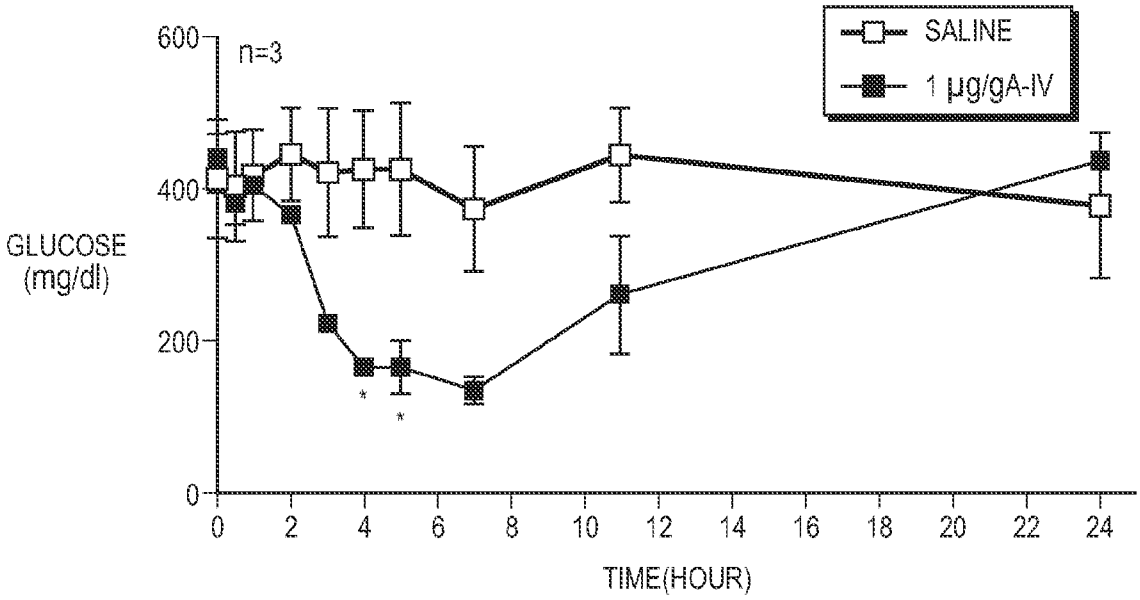

SALINE
1 µg/gA-IV
n=3
GLUCOSE
(mg/dl)
600
400
200
0
0
2
4
6
8
10
12
14
16
18
20
22
24
TIME(HOUR)

FIG. 9

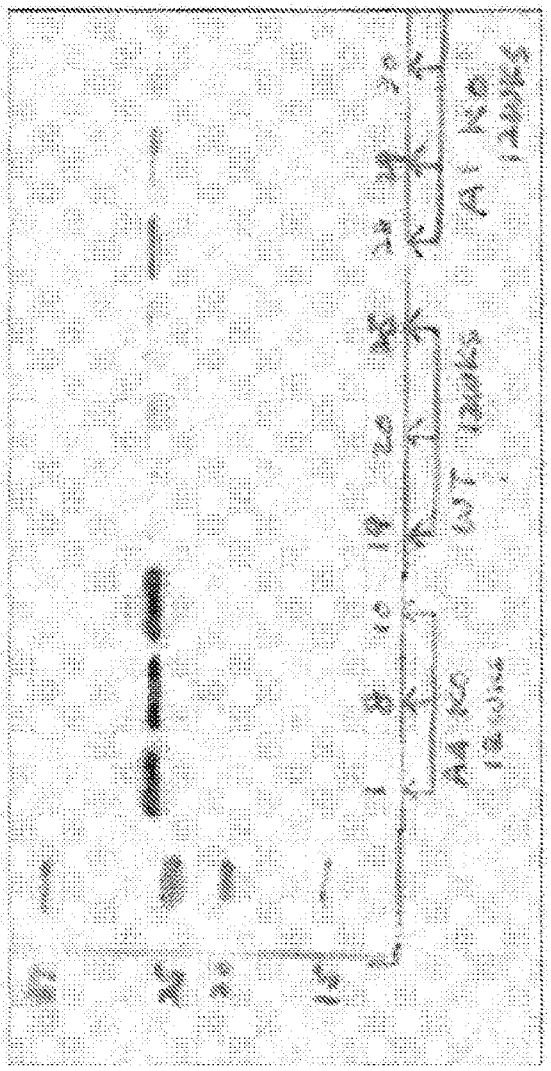


FIG. 10

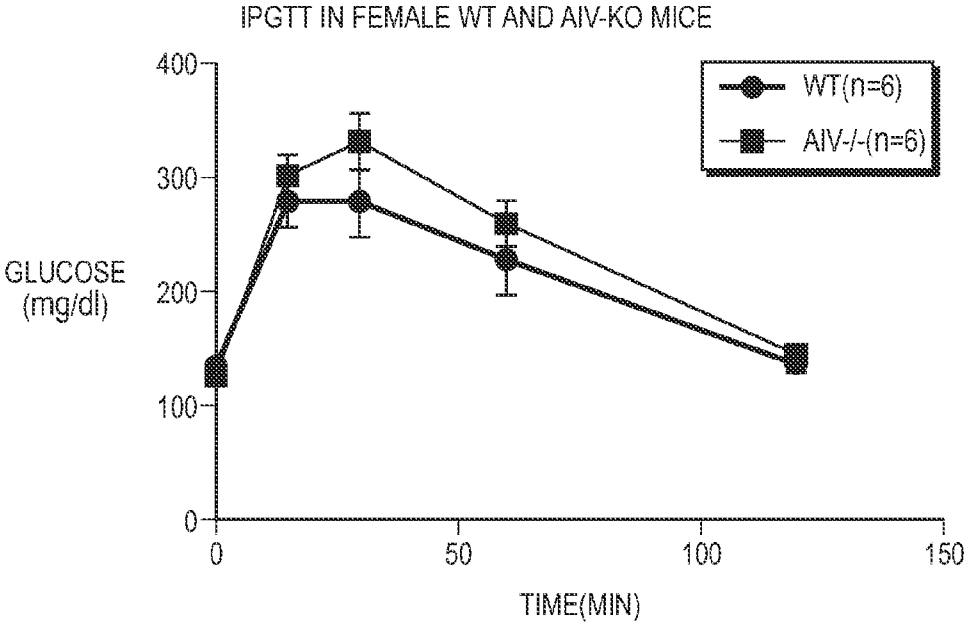

IPGTT IN FEMALE WT AND AIV-KO MICE
WT(n=6)
AIV-/-(n=6)
GLUCOSE (mg/dl)
400
300
200
100
0
0
50
100
150
TIME(MIN)

FIG. 11

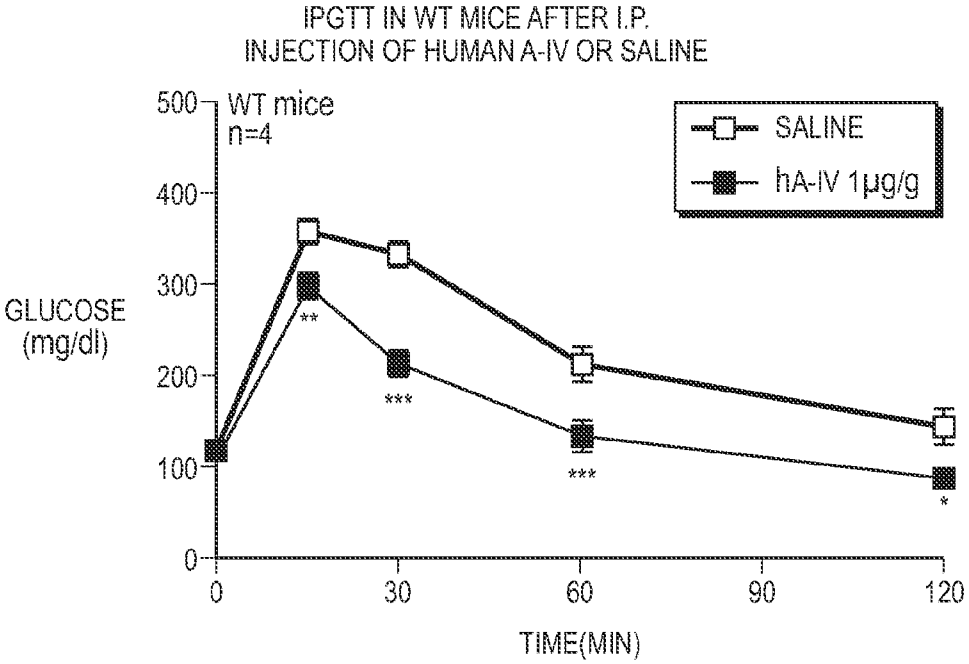

IPGTT IN WT MICE AFTER I.P.
INJECTION OF HUMAN A-IV OR SALINE
WT mice
n=4
SALINE
hA-IV 1µg/g
GLUCOSE (mg/dl)
500
400
300
200
100
0
**
***
***
*
0
30
60
90
120
TIME(MIN)

FIG. 12

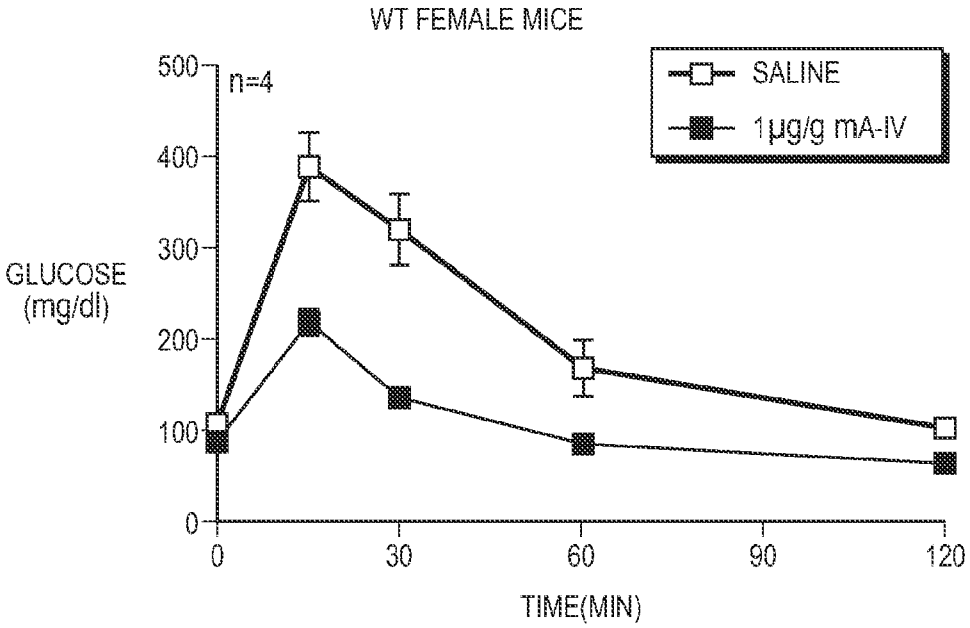

WT FEMALE MICE
n=4
SALINE
1µg/g mA-IV
GLUCOSE
(mg/dl)
500
400
300
200
100
0
0
30
60
90
120
TIME(MIN)

FIG. 13

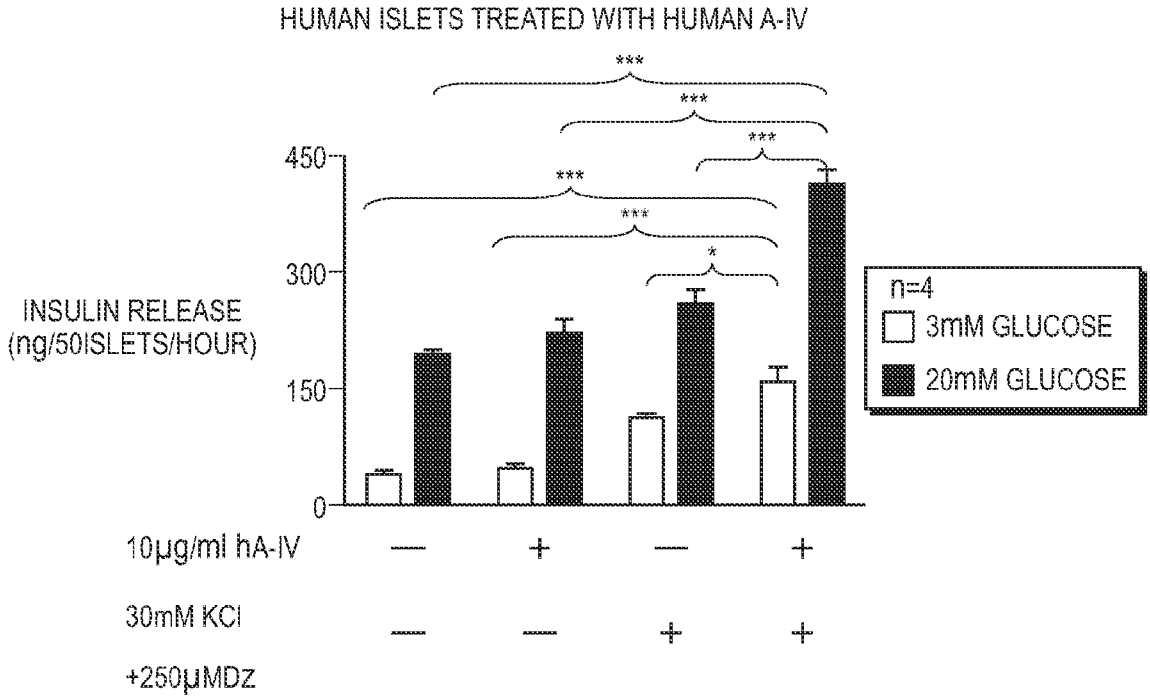

HUMAN ISLETS TREATED WITH HUMAN A-IV
***
***
***
***
***
*
450
300
150
0
INSULIN RELEASE
(ng/50ISLETS/HOUR)
n=4
3mM GLUCOSE
20mM GLUCOSE
10µg/ml hA-IV
30mM KCl
+250µMDz

FIG. 14

EVSADQVATVMWDYFSQLSNNAKEAVEHLQKSELTQQLNALFQDKLGEVNTYAGDLQ
KKLVPFATELHERLAKDSEKLKEEIGKELEELRARLLPHANEVSQKIGDNLRELQQRLEP
YADQLRTQVNTQAEQLRRQLTPYAQRMERVLRENADSLQASLRPHADELKAKIDQNVE
ELKGRLTPYADEFKVKIDQTVEELRRSLAPYAQDTQEKLNHQLEGLTFQMKKNAEELK
ARISASAEELRQRLAPLAEDVRGNLRGNTEGLQKSLAELGGHLDQQVEEFRRRVEPYGE
NFNKALVQQMEQLRQKLGPHAGDVEGHLSFLEKDLRDKVNSFFSTFKEKESQDKTLSLP
ELEQQQEQQQEQQQEQVQMLAPLES

SEQ ID NO. 1

FIG. 15

EVTSDQVANVVWDYFTQLSNNAKEAVEQFQKTDVQQLSTLFASTYADGVHNKLVPFV
VQLSGHLAQETERVKEEIKKELEDLRDRKTQTFGENMQKLQEHLKPYAVDLQDQINTQ
TQEMKLQLTPYIQRMQTTIKENVDNLHTSMMPLATNLKDKFNRNMEELKGHLTPRANE
LKATIDQNLEDLRRSLAPLTVGVQEKLNHQMEGLAFQMKKNAEELQTKVSAKIDQLQK
NLAPLVEDVQSKVKGNTEGLQKSLEDLNRQLEQQVEEFRRTVEPMGEMFNKALVQQLE
QFRQQLGPNSGEVESHLSFLEKSLREKVNSFMSTLEKKGSPDQPQALPLPEQAQEQAQE
QAQEQVQPKPLES

SEQ ID NO. 2

FIG. 16

GEVSADQVATVMWDYFSQLSNNAKEAVEHLQKSELTQQLNALFQDKLGEVNTYAGDL
QKKLVPFATELHERLAKDSEKLKEEIGKELEELRARLLPHANEVSQKIGDNLRELQQRLE
PYADQLRTQVNTQAEQLRRQLTPYAQRMERVLRENADSLQASLRPHADELKAKIDQNV
EELKGRLTPYADEFKVKIDQTVEELRRSLAPYAQDTQEKLNHQLEGLTFQMKKNAEEL
KARISASAEELRQRLAPLAEDVRGNLRGNTEGLQKSLAELGGHLDQQVEEFRRRVEPYG
ENFNKALVQQMEQLRQKLGPHAGDVEGHLSFLEKDLRDKVNSFFSTFKEKESQDKTLS
LPELEQQQEQQQEQQQEQVQMLAPLES

SEQ ID NO. 3

FIG. 17

X_1EVSADQVATVMWDYFSQLSNNAKEAVEHLQKSELTQQLNALFQDKLGEVNTYAGD
LQKKLVPFATELHERLAKDSEKLKEEIGKELEELRARLLPHANEVSQKIGDNLRELQQRL
EPYADQLRTQVNTQAEQLRRQLTPYAQRMERVLRENADSLQASLRPHADX$_2$LKAKIDQ
NVEELKGRLTPYADEFKVKIDQTVEELRRSLAPYAQDTQEKLNHQLEGLTFQMKKNAE
ELKARISASAEELRQRLAPLAEDVRGNLRGNTEGLQKSLAELGGHLDQQVEEFRRRVEP
YGENFNKALVQQMEQLRQKLGPHAGDVEGHLSFLEKDLRDKVNSFFSTFKEKESQDKX
$_3$L*S*LPELEQQQEQX$_3$*Q*EQQQEQVQMLAPLES

X_1 is G, A, V or absent

X_2 is E or K

X_3 is T or S

X_4 is Q or H

SEQ ID NO. 4

FIG. 18

GTCAGTGCTGACCAGGTGGCCACAGTGATGTGGGACTACTTCAGCCAGCTGAGCAA
CAATGCCAAGGAGGCCGTGGAACATCTCCAGAAATCTGAACTCACCCAGCAACTCA
ATGCCCTCTTCCAGGACAAACTTGGAGAAGTGAACACTTACGCAGGTGACCTGCAG
AAGAAGCTGGTGCCCTTTGCCACCGAGCTGCATGAACGCCTGGCCAAGGACTCGGA
GAAACTGAAGGAGGAGATTGGGAAGGAGCTGGAGGAGCTGAGGGCCCGGCTGCTG
CCCCATGCCAATGAGGTGAGCCAGAAGATCGGGGACAACCTGCGAGAGCTTCAGCA
GCGCCTGGAGCCCTACGCGGACCAGCTGCGCACCCAGGTCAACACGCAGGCCGAGC
AGCTGCGGCGCCAGCTGACCCCCTACGCACAGCGCATGGAGAGAGTGCTGCGGGAG
AACGCCGACAGCCTGCAGGCCTCGCTGAGGCCCCACGCCGACGAGCTCAAGGCCAA
GATCGACCAGAACGTGGAGGAGCTCAAGGGACGCCTTACGCCCTACGCTGACGAAT
TCAAAGTCAAGATTGACCAGACCGTGGAGGAGCTGCGCCGCAGCCTGGCTCCCTAT
GCTCAGGACACGCAGGAGAAGCTCAACCACCAGCTTGAGGGCCTGACCTTCCAGAT
GAAGAAGAACGCCGAGGAGCTCAAGGCCAGGATCTCGGCCAGTGCCGAGGAGCTG
CGGCAGAGGCTGGCGCCCTTGGCCGAGGACGTGCGTGGCAACCTGAGGGGCAACAC
CGAGGGGCTGCAGAAGTCACTGGCAGAGCTGGGTGGGCACCTGGACCAGCAGGTGG
AGGAGTTCCGACGCCGGGTGGAGCCCTACGGGGAAAACTTCAACAAAGCCCTGGTG
CAGCAGATGGAACAGCTCAGGCAGAAACTGGGCCCCCATGCGGGGGACGTGGAAG
GCCACCTGAGCTTCCTGGAGAAGGACCTGAGGGACAAGGTCAACTCCTTCTTCAGC
ACCTTCAAGGAGAAAGAGAGCCAGGACAAGACTCTCTCCCTCCCTGAGCTCGAGCA
ACAGCAGGAACAGCAGCAGGAGCAGCAGCAGGAGCAGGTGCAGATGCTGGCCCCT
TTGGAGAGC

SEQ ID NO. 5

FIG. 19

FIG. 20: OmpA-Apo A-IV optimised sequence

```
                 M  K   K  T  A  I   A  I  A   V  A  L   A  G  F  A ·
   1 AGGAGGTAAA ACATATGAAA AAGACAGCTA TCGCGATTGC AGTGGCACTG GCTGGTTTCG
      · T  V  A   Q  A  E   V  S  A  D   Q  V  A   T  V  M   W  D  Y  F ·
  61 CTACCGTAGC GCAGGCCGAA GTAAGCGCAG ATCAGGTAGC AACGGTAATG TGGGATTATT
      · S  Q  L   S  N  N   A  K  E  A   V  E  H   L  Q  K   S  E  L  T ·
 121 TTAGCCAATT AAGCAACAAC GCAAAAGAGG CCGTGGAGCA CTTGCAGAAG AGCGAGCTGA
      · Q  Q  L   N  A  L   F  Q  D  K   L  G  E   V  N  T   Y  A  G  D ·
 181 CCCAGCAACT GAACGCTCTG TTCCAGGACA AGTTGGGTGA GGTTAACACG TATGCGGGCG
      · L  Q  K   K  L  V   P  F  A  T   E  L  H   E  R  L   A  K  D  S ·
 241 ATCTGCAGAA GAAACTGGTG CCGTTCGCGA CCGAACTGCA CGAGCGCCTG GCGAAGGATA
      · E  K  L   K  E  E   I  G  K  E   L  E  E   L  R  A   R  L  L  P ·
 301 GCGAGAAACT GAAAGAAGAG ATCGGCAAAG AGCTGGAAGA GCTGCGTGCG CGCCTGCTGC
      · H  A  N   E  V  S   Q  K  I  G   D  N  L   R  E  L   Q  Q  R  L ·
 361 CACATGCGAA CGAGGTGAGC CAAAAGATCG GTGACAATCT GCGCGAGCTG CAGCAGCGCC
      · E  P  Y   A  D  Q   L  R  T  Q   V  N  T   Q  A  E   Q  L  R  R ·
 421 TGGAGCCGTA CGCTGACCAG CTGCGTACCC AAGTTAACAC GCAAGCCGAG CAATTGCGTC
      · Q  L  T   P  Y  A   Q  R  M  E   R  V  L   R  E  N   A  D  S  L ·
 481 GTCAACTGAC TCCGTACGCG CAGCGTATGG AGCGTGTCCT GCGTGAGAAT GCGGACAGCC
      · Q  A  S   L  R  P   H  A  D  E   L  K  A   K  I  D   Q  N  V  E ·
 541 TGCAAGCATC CCTGCGTCCT CACGCGGATG AGCTGAAGGC AAAAATCGAC CAGAATGTTG
      · E  L  K   G  R  L   T  P  Y  A   D  E  F   K  V  K   I  D  Q  T ·
 601 AAGAACTGAA AGGTCGTCTG ACCCCGTACG CAGACGAGTT CAAAGTCAAA ATTGACCAAA
      · V  E  E   L  R  R   S  L  A  P   Y  A  Q   D  T  Q   E  K  L  N ·
 661 CGGTTGAAGA GTTGCGCCGC AGCCTGGCGC CGTATGCCCA GGATACCCAA GAAAAGCTGA
      · H  Q  L   E  G  L   T  F  Q  M   K  K  N   A  E  E   L  K  A  R ·
 721 ATCATCAGCT GGAAGGCCTG ACCTTCCAGA TGAAGAAGAA TGCCGAAGAG TTGAAAGCTC
      · I  S  A   S  A  E   E  L  R  Q   R  L  A   P  L  A   E  D  V  R ·
 781 GTATTTCGGC GTCTGCGGAA GAACTGCGCC AACGTCTGGC CCCGTTGGCG GAAGATGTGC
      · G  N  L   R  G  N   T  E  G  L   Q  K  S   L  A  E   L  G  G  H ·
 841 GCGGTAATCT GCGTGGCAAC ACCGAAGGTC TGCAAAAGAG CCTGGCCGAG TTGGGTGGCC
      · L  D  Q   Q  V  E   E  F  R  R   R  V  E   P  Y  G   E  N  F  N ·
 901 ATCTGGATCA ACAGGTTGAA GAATTTCGTC GTCGTGTGGA ACCGTACGGC GAGAACTTCA
      · K  A  L   V  Q  Q   M  E  Q  L   R  Q  K   L  G  P   H  A  G  D ·
 961 ATAAGGCGCT GGTGCAGCAA ATGGAGCAGC TGCGCCAGAA GCTGGGTCCG CACGCTGGTG
      · V  E  G   H  L  S   F  L  E  K   D  L  R   D  K  V   N  S  F  F ·
1021 ACGTCGAAGG TCACCTGTCC TTTCTGGAGA AAGACTTGCG TGATAAAGTC AATAGCTTCT
      · S  T  F   K  E  K   E  S  Q  D   K  T  L   S  L  P   E  L  E  Q ·
```

```
     ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
1081 TTTCTACGTT TAAAGAGAAA GAGAGCCAAG ACAAGACCCT GTCCCTGCCG GAGCTGGAAC
     · Q Q E  Q Q Q  E Q Q Q  E Q V  Q M L  A P L E ·
     ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
1141 AGCAACAGGA GCAGCAGCAG GAGCAACAGC AAGAACAAGT TCAGATGTTG GCACCGCTGG
                XhoI
                ~~~~~~
     · S                        (SEQ ID NO:12)
     ~~~~~
1201 AAAGCTAATG ACTCGAG         (SEQ ID NO:13)
```

FIG. 20 (Continued)

FIG. 21: PelB-Apo A-IV optimised sequence

```
                    ~~~~~~
                      M  K  Y  L  L  P  T  A  A  A  G  L  L  L  L
                    ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
  1 GAAGGAGATA TACATATGAA ATACCTGCTG CCGACCGCTG CTGCTGGTCT GCTGCTCCTC
    A  A  Q  P  A  M  A  E  V  S  A  D  Q  V  A  T  V  M  W  D
    ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
 61 GCTGCCCAGC CGGCGATGGC CGAAGTAAGC GCAGATCAGG TAGCAACGGT AATGTGGGAT
    Y  F  S  Q  L  S  N  N  A  K  E  A  V  E  H  L  Q  K  S  E
    ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
121 TATTTTAGCC AATTAAGCAA CAACGCAAAA GAGGCCGTGG AGCACTTGCA GAAGAGCGAG
    L  T  Q  Q  L  N  A  L  F  Q  D  K  L  G  E  V  N  T  Y  A
    ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
181 CTGACCCAGC AACTGAACGC TCTGTTCCAG GACAAGTTGG GTGAGGTTAA CACGTATGCG
          PstI
        ~~~~~~~
    G  D  L  Q  K  K  L  V  P  F  A  T  E  L  H  E  R  L  A  K
    ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
241 GGCGATCTGC AGAAGAAACT GGTGCCGTTC GCGACCGAAC TGCACGAGCG CCTGGCGAAG
    D  S  E  K  L  K  E  E  I  G  K  E  L  E  E  L  R  A  R  L
    ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
301 GATAGCGAGA AACTGAAAGA AGAGATCGGC AAAGAGCTGG AAGAGCTGCG TGCGCGCCTG
                                                        PstI
                                                      ~~~~~~
    L  P  H  A  N  E  V  S  Q  K  I  G  D  N  L  R  E  L  Q  Q
    ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
361 CTGCCACATG CGAACGAGGT GAGCCAAAAG ATCGGTGACA ATCTGCGCGA GCTGCAGCAG
    R  L  E  P  Y  A  D  Q  L  R  T  Q  V  N  T  Q  A  E  Q  L
    ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
421 CGCCTGGAGC CGTACGCTGA CCAGCTGCGT ACCCAAGTTA ACACGCAAGC CGAGCAATTG
    R  R  Q  L  T  P  Y  A  Q  R  M  E  R  V  L  R  E  N  A  D
    ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
481 CGTCGTCAAC TGACTCCGTA CGCGCAGCGT ATGGAGCGTG TCCTGCGTGA GAATGCGGAC
    S  L  Q  A  S  L  R  P  H  A  D  E  L  K  A  K  I  D  Q  N
    ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
541 AGCCTGCAAG CATCCCTGCG TCCTCACGCG GATGAGCTGA AGGCAAAAAT CGACCAGAAT
    V  E  E  L  K  G  R  L  T  P  Y  A  D  E  F  K  V  K  I  D
    ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
601 GTTGAAGAAC TGAAAGGTCG TCTGACCCCG TACGCAGACG AGTTCAAAGT CAAAATTGAC
    Q  T  V  E  E  L  R  R  S  L  A  P  Y  A  Q  D  T  Q  E  K
    ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
661 CAAACGGTTG AAGAGTTGCG CCGCAGCCTG GCGCCGTATG CCCAGGATAC CCAAGAAAAG
    L  N  H  Q  L  E  G  L  T  F  Q  M  K  K  N  A  E  E  L  K
    ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
721 CTGAATCATC AGCTGGAAGG CCTGACCTTC CAGATGAAGA AGAATGCCGA AGAGTTGAAA
    A  R  I  S  A  S  A  E  E  L  R  Q  R  L  A  P  L  A  E  D
    ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
781 GCTCGTATTT CGGCGTCTGC GGAAGAACTG CGCCAACGTC TGGCCCCGTT GGCGGAAGAT
    V  R  G  N  L  R  G  N  T  E  G  L  Q  K  S  L  A  E  L  G
    ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
841 GTGCGCGGTA ATCTGCGTGG CAACACCGAA GGTCTGCAAA AGAGCCTGGC CGAGTTGGGT
    G  H  L  D  Q  Q  V  E  E  F  R  R  R  V  E  P  Y  G  E  N
    ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
901 GGCCATCTGG ATCAACAGGT TGAAGAATTT CGTCGTCGTG TGGAACCGTA CGGCGAGAAC
    F  N  K  A  L  V  Q  Q  M  E  Q  L  R  Q  K  L  G  P  H  A
    ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
961 TTCAATAAGG CGCTGGTGCA GCAAATGGAG CAGCTGCGCC AGAAGCTGGG TCCGCACGCT
    G  D  V  E  G  H  L  S  F  L  E  K  D  L  R  D  K  V  N  S
```

```
     ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
1021 GGTGACGTCG AAGGTCACCT GTCCTTTCTG GAGAAAGACT TGCGTGATAA AGTCAATAGC
      F  F  S  T   F  K  E   K  E  S   Q  D  K  T   L  S  L   P  E  L
     ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
1081 TTCTTTTCTA CGTTTAAAGA GAAAGAGAGC CAAGACAAGA CCCTGTCCCT GCCGGAGCTG
      E  Q  Q  Q   E  Q  Q   Q  E  Q   Q  Q  E  Q   V  Q  M   L  A  P
     ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
1141 GAACAGCAAC AGGAGCAGCA GCAGGAGCAA CAGCAAGAAC AAGTTCAGAT GTTGGCACCG
                     XhoI
                     ~~~~~~~
      L  E  S                          (SEQ ID NO:14)
     ~~~~~~~~~
1201 CTGGAAAGCT AATGACTCGA G           (SEQ ID NO:15)
```

FIG. 21 (Continued)

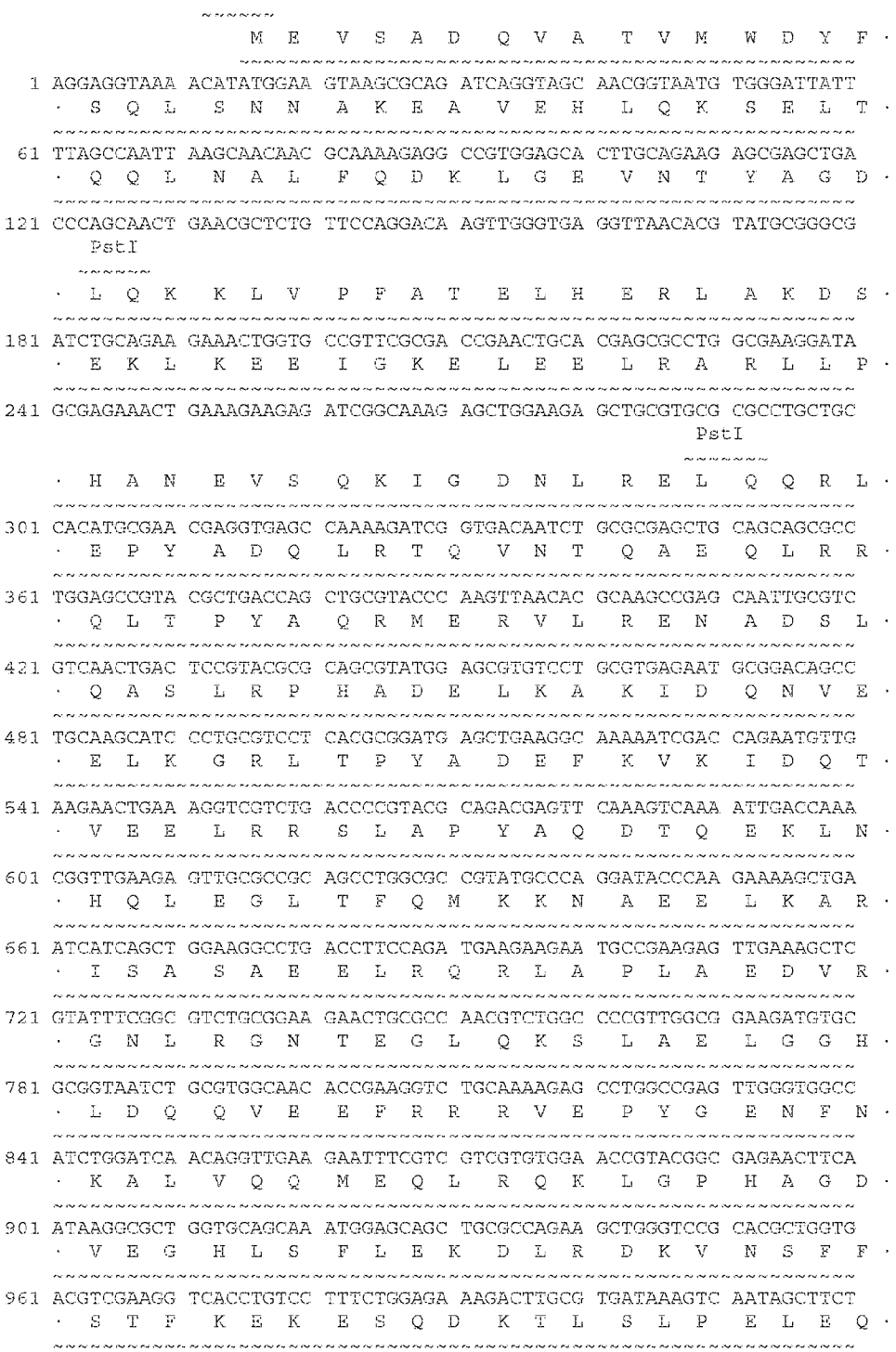
FIG. 22: ENX-Apo A-IV optimised sequence

```
                      M  F   K  F  K   K  N  F  L   V  G  L   S  A  A
                     ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
   1 GAAGGAGATA TACATATGTT TAAGTTTAAA AAGAATTTCT TAGTTGGATT ATCGGCAGCT
     L  M  S  I   S  L  F   S  A  T   A  S  A  E   V  S  A   D  Q  V
     ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
  61 TTAATGAGTA TTAGCTTGTT TTCGGCAACC GCCTCTGCAG AAGTAAGCGC AGATCAGGTA
     A  T  V  M   W  D  Y   F  S  Q   L  S  N  N   A  K  E   A  V  E
     ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
 121 GCAACGGTAA TGTGGGATTA TTTTAGCCAA TTAAGCAACA ACGCAAAAGA GGCCGTGGAG
     H  L  Q  K   S  E  L   T  Q  Q   L  N  A  L   F  Q  D   K  L  G
     ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
 181 CACTTGCAGA AGAGCGAGCT GACCCAGCAA CTGAACGCTC TGTTCCAGGA CAAGTTGGGT
     E  V  N  T   Y  A  G   D  L  Q   K  K  L  V   P  F  A   T  E  L
     ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
 241 GAGGTTAACA CGTATGCGGG CGATCTGCAG AAGAAACTGG TGCCGTTCGC GACCGAACTG
     H  E  R  L   A  K  D   S  E  K   L  K  E  E   I  G  K   E  L  E
     ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
 301 CACGAGCGCC TGGCGAAGGA TAGCGAGAAA CTGAAAGAAG AGATCGGCAA AGAGCTGGAA
     E  L  R  A   R  L  L   P  H  A   N  E  V  S   Q  K  I   G  D  N
     ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
 361 GAGCTGCGTG CGCGCCTGCT GCCACATGCG AACGAGGTGA GCCAAAAGAT CGGTGACAAT
     L  R  E  L   Q  Q  R   L  E  P   Y  A  D  Q   L  R  T   Q  V  N
     ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
 421 CTGCGCGAGC TGCAGCAGCG CCTGGAGCCG TACGCTGACC AGCTGCGTAC CCAAGTTAAC
     T  Q  A  E   Q  L  R   R  Q  L   T  P  Y  A   Q  R  M   E  R  V
     ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
 481 ACGCAAGCCG AGCAATTGCG TCGTCAACTG ACTCCGTACG CGCAGCGTAT GGAGCGTGTC
     L  R  E  N   A  D  S   L  Q  A   S  L  R  P   H  A  D   E  L  K
     ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
 541 CTGCGTGAGA ATGCGGACAG CCTGCAAGCA TCCCTGCGTC CTCACGCGGA TGAGCTGAAG
     A  K  I  D   Q  N  V   E  E  L   K  G  R  L   T  P  Y   A  D  E
     ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
 601 GCAAAAATCG ACCAGAATGT TGAAGAACTG AAAGGTCGTC TGACCCCGTA CGCAGACGAG
     F  K  V  K   I  D  Q   T  V  E   E  L  R  R   S  L  A   P  Y  A
     ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
 661 TTCAAAGTCA AAATTGACCA AACGGTTGAA GAGTTGCGCC GCAGCCTGGC GCCGTATGCC
     Q  D  T  Q   E  K  L   N  H  Q   L  E  G  L   T  F  Q   M  K  K
     ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
 721 CAGGATACCC AAGAAAAGCT GAATCATCAG CTGGAAGGCC TGACCTTCCA GATGAAGAAG
     N  A  E  E   L  K  A   R  I  S   A  S  A  E   E  L  R   Q  R  L
     ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
 781 AATGCCGAAG AGTTGAAAGC TCGTATTTCG GCGTCTGCGG AAGAACTGCG CCAACGTCTG
     A  P  L  A   E  D  V   R  G  N   L  R  G  N   T  E  G   L  Q  K
     ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
 841 GCCCCGTTGG CGGAAGATGT GCGCGGTAAT CTGCGTGGCA ACACCGAAGG TCTGCAAAAG
     S  L  A  E   L  G  G   H  L  D   Q  Q  V  E   E  F  R   R  R  V
     ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
 901 AGCCTGGCCG AGTTGGGTGG CCATCTGGAT CAACAGGTTG AAGAATTTCG TCGTCGTGTG
     E  P  Y  G   E  N  F   N  K  A   L  V  Q  Q   M  E  Q   L  R  Q
     ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
 961 GAACCGTACG GCGAGAACTT CAATAAGGCG CTGGTGCAGC AAATGGAGCA GCTGCGCCAG
     K  L  G  P   H  A  G   D  V  E   G  H  L  S   F  L  E   K  D  L
     ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
1021 AAGCTGGGTC CGCACGCTGG TGACGTCGAA GGTCACCTGT CCTTTCTGGA GAAAGACTTG
     R  D  K  V   N  S  F   F  S  T   F  K  E  K   E  S  Q   D  K  T
     ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
1081 CGTGATAAAG TCAATAGCTT CTTTTCTACG TTTAAAGAGA AAGAGAGCCA AGACAAGACC
```

```
     L  S  L  P   E  L  E   Q  Q  Q   E  Q  Q  Q   E  Q  Q   Q  E  Q
     ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
1141 CTGTCCCTGC CGGAGCTGGA ACAGCAACAG GAGCAGCAGC AGGAGCAACA GCAAGAACAA
                                        XhoI
                                       ~~~~~~
     V  Q  M  L   A  P  L   E  S                          (SEQ ID NO:16)
     ~~~~~~~~~~~~~~~~~~~~~~~~~~~~
1201 GTTCAGATGT TGGCACCGCT GGAAAGCTAA TGACTCGAG           (SEQ ID NO:17)
```

FIG. 22 (Continued)

FIG. 23: Apo A-IV optimised sequence



```
1021 TTTCTACGTT TAAAGAGAAA GAGAGCCAAG ACAAGACCCT GTCCCTGCCG GAGCTGGAAC
     ·  Q  Q  E   Q  Q  Q   E  Q  Q  Q   E  Q  V   Q  M  L   A  P  L  E ·
     ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
1081 AGCAACAGGA GCAGCAGCAG GAGCAACAGC AAGAACAAGT TCAGATGTTG GCACCGCTGG
                  XhoI
                 ~~~~~~
                  AvaI
                 ~~~~~~~
     ·  S                          (SEQ ID NO:18)
     ~~~~~
1141 AAAGCTAATG ACTCGAG            (SEQ ID NO:19)
```

FIG. 23 (Continued)

Output for 'Native'

```
Name:  Native   Length:  396
MFLKAVVLTLALVAVAGARAEVSADQVATVMWDYFSQLSNNAKEAVEHLQKSELTQQLNALFQDKLGEVNTYAGDLQKKL      80
VPFATELHERLAKDSEKLKEEIGKELEELRARLLPHANEVSQKIGDNLRELQQRLEPYADQLRTQVNTQAEQLRRQLDPL     160
AQRMERVLRENADSLQASLRPHADELKAKIDQNVEELKGRLTPYADEFKVKIDQTVEELRRSLAPYAQDTQEKLNHQLEG     240
LTFQMKKNAEELKARISASAEELRQRLAPLAEDVRGNLKGNTEGLQKSLAELGGHLDQQVEEFRRRVEPYGENFNKALVQ     320
QMEQLRQKLGPHAGDVEGHLSFLEKDLRDKVNSFFSTFKEKESQDKTLSLPELEQQQEQQQEQQQEQVQMLAPLES
.....                                                                              80
.....                                                                             160
.....                                                                             240
.....                                                                             320
.....                                                                             400

(Threshold=0.5)

No sites predicted in this sequence.
```

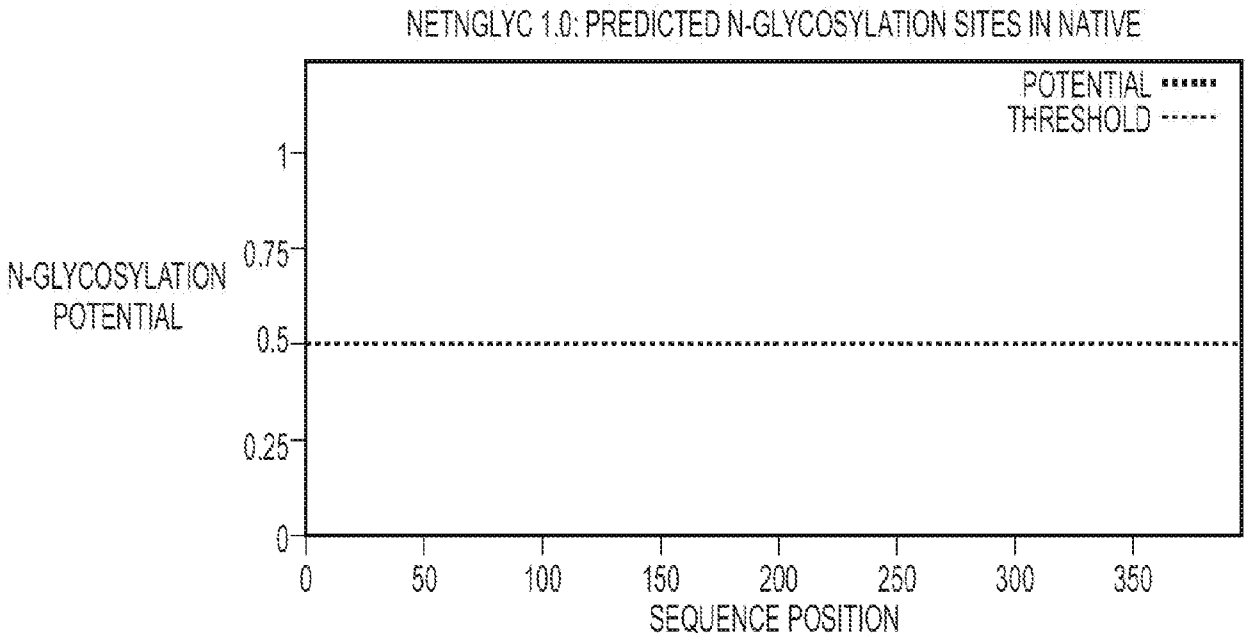


Figure 24A

```
Name:  1Missense_Pro_P__to_His_H__393   Length:  396
MFLKAVVLTLALVAVAGARAEVSADQVATVMWDYFSQLSNNAKEAVEHLQKSELTQQLNALFQDKLGEVNTYAGDLQKKL      80
VPFATELHERLAKDSEKLKEEIGKELEELRARLLPHANEVSQKIGDNLRELQQRLEPYADQLRTQVNTQAEQLRRQLDPL     160
AQRMERVLRENADSLQASLRPHADELKAKIDQNVEELKGRLTPYADEFKVKIDQTVEELRRSLAPYAQDTQEKLNHQLEG     240
LTFQMKKNAEELKARISASAEELRQRLAPLAEDVRGNLKGNTEGLQKSLAELGGHLDQQVEEFRRRVEPYGENFNKALVQ     320
QMEQLRQKLGPHAGDVEGHLSFLEKDLRDKVNSFFSTFKEKESQDKTLSLPELEQQQEQQQEQQQEQVQMLAHLES
.....                                                                                  80
.....                                                                                 160
.....                                                                                 240
.....                                                                                 320
.....                                                                                 400

(Threshold=0.5)

No sites predicted in this sequence.
```

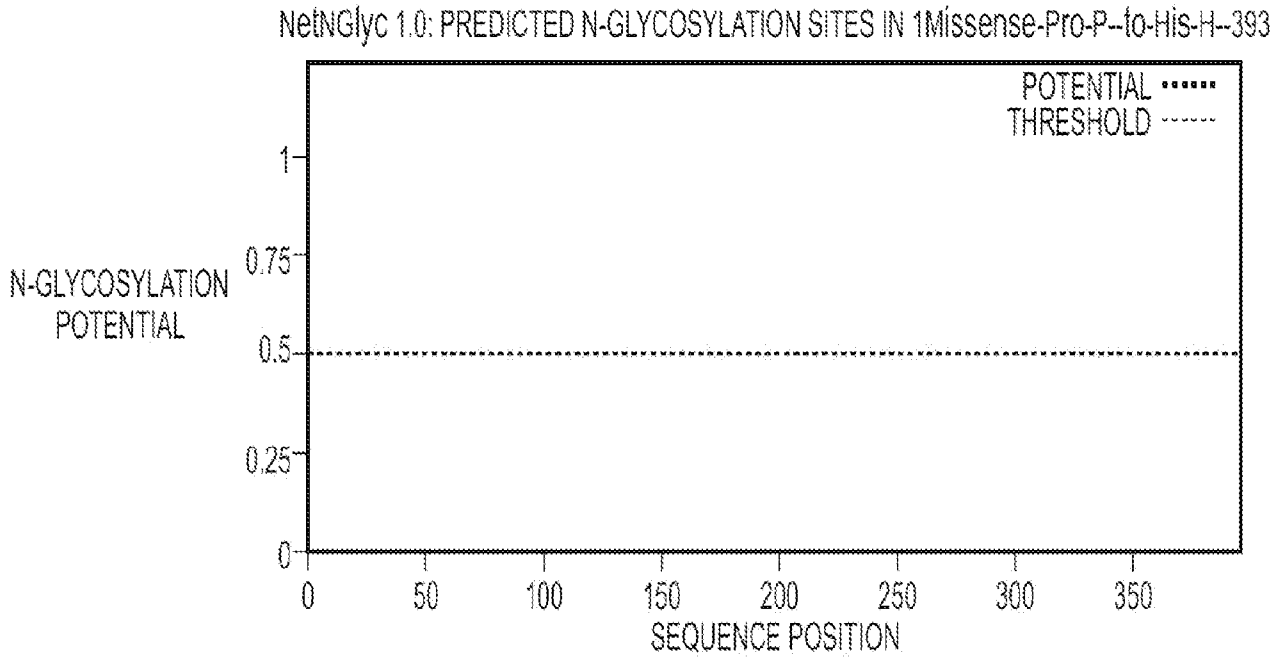


Figure 24B

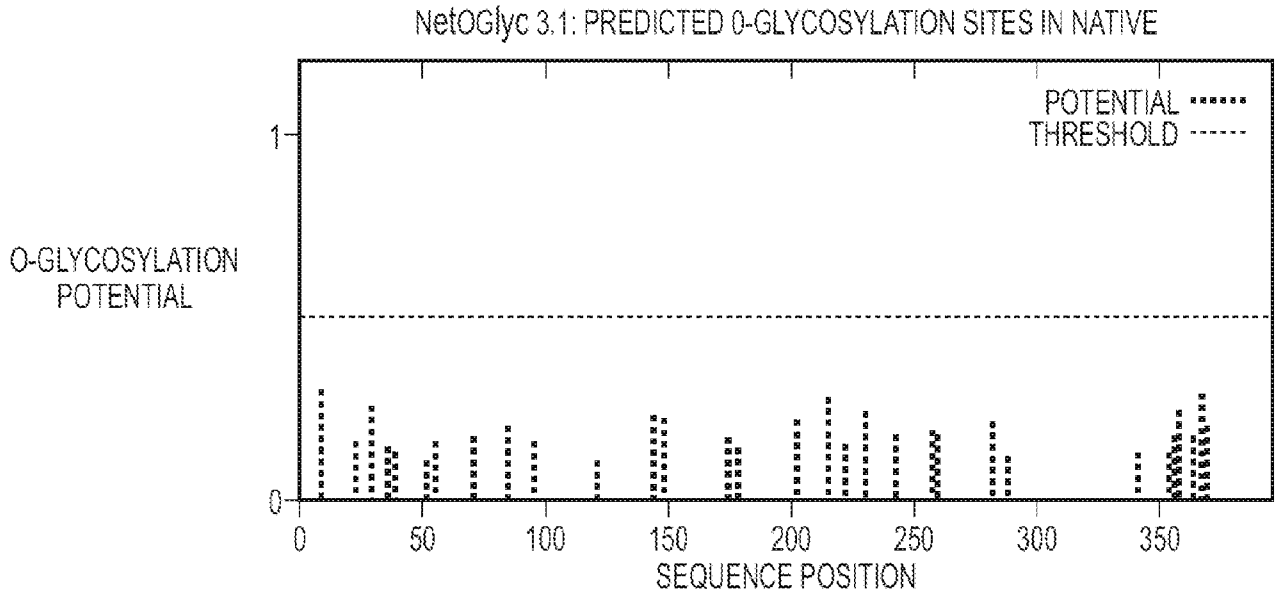


Figure 25A

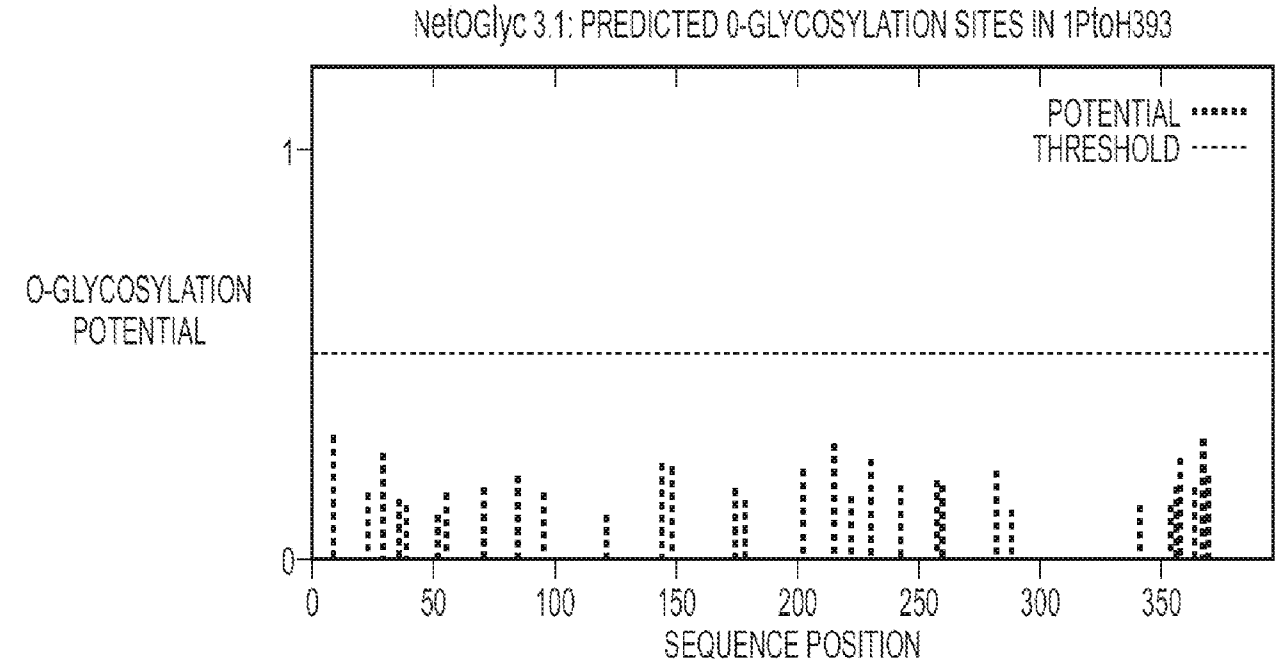


Figure 25B

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2012/066314

A. CLASSIFICATION OF SUBJECT MATTER
INV. A61K38/17 C07K14/775 A61P3/10
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
A61K C07K A61P

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, BIOSIS, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	DATABASE BIOSIS [Online] BIOSCIENCES INFORMATION SERVICE, PHILADELPHIA, PA, US; July 2002 (2002-07), OKUMURA TOSHIKATSU ET AL: "Physiology of the small intestine in the glycemic control and the treatment of diabetes mellitus", XP002676412, Database accession no. PREV200200415101 abstract -/--	1-44

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
22 January 2013	30/01/2013

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Merckling-Ruiz, V

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2012/066314

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	& OKUMURA TOSHIKATSU ET AL: "Physiology of the small intestine in the glycemic control and the treatment of diabetes mellitus", FOLIA PHARMACOLOGICA JAPONICA, vol. 120, no. 1, July 2002 (2002-07), pages 29-31, ISSN: 0015-5691	
A	WO 2009/116861 A2 (PODICEPS B V [NL]; DE WIT NICOLE JOHANNA WILHELMI [NL]; VAN DER MEER R) 24 September 2009 (2009-09-24) see page 1, pages 9-10 and Cl.1	1-44
X	WO 93/15198 A1 (RHONE POULENC RORER SA [FR]) 5 August 1993 (1993-08-05) see abstract and claims 1-17	25-39

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2012/066314

Box No. I Nucleotide and/or amino acid sequence(s) (Continuation of item 1.c of the first sheet)

1. With regard to any nucleotide and/or amino acid sequence disclosed in the international application and necessary to the claimed invention, the international search was carried out on the basis of:

   a. (means)

   ☐ on paper

   ☒ in electronic form

   b. (time)

   ☒ in the international application as filed

   ☐ together with the international application in electronic form

   ☐ subsequently to this Authority for the purpose of search

2. ☐ In addition, in the case that more than one version or copy of a sequence listing and/or table relating thereto has been filed or furnished, the required statements that the information in the subsequent or additional copies is identical to that in the application as filed or does not go beyond the application as filed, as appropriate, were furnished.

3. Additional comments:

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2012/066314

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2009116861 A2	24-09-2009	AU 2009226246 A1	24-09-2009
		CA 2719001 A1	24-09-2009
		EP 2257814 A2	08-12-2010
		US 2011107439 A1	05-05-2011
		WO 2009116861 A2	24-09-2009
WO 9315198 A1	05-08-1993	CA 2125877 A1	05-08-1993
		EP 0624194 A1	17-11-1994
		FR 2686605 A1	30-07-1993
		JP H07503367 A	13-04-1995
		WO 9315198 A1	05-08-1993

摘要

本发明公开了治疗需要的受试者的 2 型糖尿病的方法和用于治疗 2 型糖尿病的药物组合物，其中本发明的方法和组合物是基于使用由蛋白质表达系统如细胞表达系统产生的非糖基化载脂蛋白 A-IV。还公开了基于施用由蛋白质表达系统产生的非糖基化载脂蛋白 A-IV 基本上恢复需要的受试者的葡萄糖耐量到正常水平的方法和降低需要的受试者的血糖水平的方法。