【DESCRIPTION】

【Invention Title】

USE OF A LONG ACTING GLP-1/GLUCAGON RECEPTOR DUAL AGONIST FOR THE TREATMENT OF NON-ALCOHOLIC FATTY LIVER DISEASE

【Technical Field】

The present invention relates to a pharmaceutical composition for the prevention or treatment of non-alcoholic fatty liver disease, including a long-acting glucagon-like peptide-1 (GLP-1)/glucagon receptor dual agonist, and a method for preventing or treating non-alcoholic fatty liver disease including administering the composition.

【Background Art】

Non-alcoholic fatty liver disease (NAFLD) is a type of a disease, showing histological organization similar to those of alcoholic liver disease, although is not associated with alcohol consumption, and is a kind of metabolic syndrome associated with non-alcoholic fatty liver (NAFL), non-alcoholic steatohepatitis (NASH), liver cirrhosis, and hepatocellular carcinomas. The occurrence of non-alcoholic fatty liver diseases increases with an increase in population with obesity and diabetes. In Korea, the annual incidence has reached approximately 16%.

Non-alcoholic fatty liver disease is known to be caused by various etiologies such as insulin resistance, lipotoxicity and inflammatory responses. Among them, the most common etiology is insulin resistance.

A lot of effort has been made to improve the insulin resistance to prevent/treat non-alcoholic fatty liver disease. For example, currently clinical trials for thiazolidnedinones

(TZD) or metformin, a kind of insulin sensitizer, have been actively conducted (see, Hepatology (2003) 38: 1008-17, J Clin Invest (2001) 108: 1167-74).

However, in the case of treatment with the TZD-based drugs, there are disadvantages of a large weight gain and slow fluid flow, and thus the use of such treatment has been known to be impossible for patients with a heart disease. In addition to the TZD-based drugs, clinical tests using GLP-1 receptor agonists such as Victoza or Byetta for non-alcoholic fatty liver disease have been actively conducted. However, in these cases, the *in vivo* half-life is extremely short, and thus repeated administrations must be made once or at least twice per day, like other polypeptide hormones. Therefore, there is a disadvantage due to inconvenience to patients. Such frequent administrations cause great pain and discomfort to patients. That is, simply using general therapeutic agents for diabetes as a therapeutic agent for non-alcoholic fatty liver disease, through the mechanism of improving insulin resistance has disadvantages such as various side-effects or patient's inconvenience. Due to these factors, when a drug known to be effective in the treatment of diabetes, such as a drug for improving insulin resistance, is directly used as a therapeutic agent for non-alcoholic fatty liver disease, various factors which may result in problems such as side-effects have been known in the art. Hence, whether a drug known to be effective in the treatment of diabetes, such as a drug for improving insulin resistance, can definitely be used as a therapeutic agent for non-alcoholic fatty liver disease, is controversial. Thus, there still remains a need to develop drugs capable of treating non-alcoholic fatty liver disease while securing patient's convenience without side-effects.

【Disclosure】

【Technical Problem】

The present inventors have made many efforts to develop a drug for the prevention or

treatment of non-alcoholic fatty liver disease, which maximizes patient's compliance while increasing the half life without side-effects such as body weight gain. As a result, the inventors have discovered that the *in vivo* half life of a long-acting GLP-1/glucagon receptor dual agonist linked to Fc fragment is greatly improved and also has an effective result of weight loss, and further liver triglyceride and blood cholesterol are decreased. The present invention has been completed on the basis of such discovery.

【Technical Solution】

An objective of the present invention is to provide a pharmaceutical composition for the prevention or treatment of non-alcoholic fatty liver disease including a long-acting glucagon-like peptide-1 (GLP-1)/glucagon receptor dual agonist.

Another objective of the present invention is to provide a method for preventing or treating non-alcoholic fatty liver disease including administering the composition to a subject suspected of or having the non-alcoholic liver disease.

【Advantageous Effects】

The long-acting GLP-1/glucagon receptor dual agonist according to the present invention can widen the choices of patients by expanding the category of drugs which had until new been applicable to the non-alcoholic fatty liver disease, and increase patient's convenience by significantly increasing the blood half life. Further, the present invention provides a new alternative that can be applied without danger to patients with diseases other than non-alcoholic fatty liver disease through reduction of side-effects such as weight gain.

【Description of Drawings】

Fig. 1 is a graph showing changes in body weight and liver weight of the long-acting GLP-1/glucagon receptor dual agonist in the high-fat, fructose and cholesterol containing high trans-fat feed intake ob/ob mouse model.

Fig. 2 is a graph showing the results of measuring collagen-1a, TNF-α, SREBP-1c mRNA of the long-acting GLP-1/glucagon receptor dual agonist in the high-fat, fructose and cholesterol containing high trans-fat feed intake ob/ob mouse model.

Fig. 3 is a graph showing the reduction of the content of the liver triglyceride and serum cholesterol of the long-acting GLP-1/glucagon receptor dual agonist in the high trans-fat feed intake DI0 mouse model.

【Best Mode】

In order to accomplish the objectives, one aspect of the present invention provides a pharmaceutical composition for prevention or treatment of non-alcoholic fatty liver disease comprising a long-acting glucagon-like peptide-1 (GLP-1)/glucagon receptor dual agonist.

The long-acting GLP-1/glucagon receptor dual agonist may be a long-acting GLP-1/glucagon receptor dual agonist which is in a conjugated form, wherein a biocompatible material or a carrier capable of increasing the duration of the activity of the dual agonist is linked to the agonist by a covalent bond or a linker.

In the case of treatment with TZD-based drugs, which are drugs for improving insulin response which is a mechanism for improving the insulin resistance, and conventional therapeutic agents of non-alcoholic fatty liver disease, there are disadvantages in that it was not possible for the treatment to apply to patients with heart diseases due to side-effects such as large weight gain and slow fluid flow. In the case of protein drugs such as peptide hormone, there are

disadvantages in that the *in vivo* half life is short and thus repeated administration is necessary. The present inventors have discovered that the long-acting GLP-1/glucagon receptor dual agonist either has no side-effects of weight gain or reduces the side effect of weight gain in various animal models of non-alcoholic liver disease and that the long-acting GLP-1/glucagon receptor dual agonist can treat non-alcoholic fatty liver disease in a form in which sustainability in blood is dramatically increased. Accordingly, the present invention has been completed to provide the use of the long-acting GLP-1/glucagon receptor dual agonist for the prevention or treatment of non-alcoholic fatty liver disease.

The composition of the present invention is characterized by either having no side effect of weight gain or reducing the side effect of weight gain.

Furthermore, the composition of the present invention can prevent or treat non-alcoholic fatty liver disease by performing at least one of the following functions: (a) reducing the expression or activity of collagen-1a, which is a fibrosis marker; (b) reducing the expression or activity of tumor necrosis factor-α (TNF-α), which is a pro-inflammatory marker; (c) reducing the expression or activity of sterol regulatory element binding protein-1c (SREBP-1c), which is a lipogenesis marker; (d) reducing liver triglycerides; and (e) reducing blood cholesterol.

In one embodiment of the present invention, the long-acting GLP-1/glucagon receptor dual agonist of the present invention was administered to various animal models of non-alcoholic fatty liver disease. As a result, it was confirmed that the body weight and liver weight were significantly decreased compared to those of a non-treated group (Fig. 1) and that there was no side-effect such as weight gain as in the use of a conventional therapeutic agent. Furthermore, it was confirmed that the expression of collagen-1a, TNF-α, SREBP-1c decreased remarkably compared to that of the non-treated group, thus preventing fibrosis, i.e., hepatic fibrosis, inhibiting inflammation, and inhibiting fat accumulation inhibition (Fig. 2). Therefore, it was confirmed that the long-acting GLP-1/glucagon receptor dual agonist of the present invention

can be used as a drug for the prevention and treatment of various non-alcoholic liver diseases. In addition, it was confirmed that liver triglycerides and blood cholesterol was significantly reduced compared to those of the non-treated group and that they were significantly reduced to a normal animal level (Fig. 3). Therefore, it was confirmed that the long-acting GLP-1/glucagon receptor dual agonist of the present invention can be used as an excellent drug for the prevention and treatment of various non-alcoholic liver diseases.

As used herein, the term "GLP-1/glucagon receptor dual agonist" may be used interchangeably with a "GLP-1/glucagon dual agonist". The GLP-1/glucagon receptor dual agonist includes all peptides, or fragments, precursors, derivatives or variants thereof which have GLP-1/glucagon dual activity, like oxyntomodulin, a native GLP-1/glucagon receptor dual agonist, and also materials that can activate the GLP-1 and glucagon receptor at the same time, but is not limited thereto. In the present invention, the GLP-1/glucagon receptor agonist may be a receptor dual-dual agonist applying the long-acting technique to overcome the short half-life, and preferably a long-acting receptor dual agonist which can be administered once a week, but is not limited thereto. Specific examples of the GLP-1/glucagon receptor dual agonist according to the present invention partially may include, for example, the GLP-1/glucagon receptor dual agonist, a derivative thereof, and a long-acting type thereof as described in Korean Patent Application Publication Nos. 10-2012-0137271 and 10-2012-0139579, whose entire contents are incorporated herein by reference.

In one embodiment of the present invention, the long-acting GLP-1/glucagon receptor dual agonist may be in a conjugate form, wherein a biocompatible material or a carrier is linked to the agonist by a covalent bond or a linker. In another embodiment, such long-acting type may be in a form, wherein a biocompatible material or a carrier can be linked directly to the GLP-1/glucagon receptor dual agonist by a covalent bond by a known genetic recombination technique. The long-acting type of the mentioned GLP-1/glucagon receptor dual agonist can

improve the half-life or bioavailability compared to a form in which the sequence of the GLP-1/glucagon receptor dual agonist is not the long-acting type but is otherwise the same. In accordance with one embodiment of the present invention, as one example of the long-acting GLP-1/glucagon receptor dual agonist, a composition in which the immunoglobulin Fc region is linked to the 30th amino acid of the GLP-1/glucagon receptor dual agonist by the non-peptide polymer linker, preferably PEG, may be used, but is not limited thereto.

As used herein, the term "biocompatible material" or "carrier" refer to materials which can increase the duration of the activity of the GLP-1/glucagon receptor dual agonist when the biocompatible material and the carrier are covalently or non-covalently linked to the GLP-1/glucagon receptor dual agonist of the present invention directly or indirectly to form a conjugate. For example, when forming the conjugate, a material which can increase the *in vivo* half-life of the GLP-1/glucagon receptor dual agonist may be a biocompatible material or carrier according to the present invention. The type of the biocompatible material or carrier that can be used to increase the half-life varies, and examples thereof may include polyethylene glycol, fatty acid, cholesterol, albumin and a fragment thereof, an albumin-binding substance, a polymer of repeating units of a specific amino acid sequence, an antibody, an antibody fragment, an Fc neonatal receptor (FcRn) binding material, an *in vivo* connective tissue, a nucleotide, fibronectin, transferrin, a saccharide, a polymer, etc. Of course, the carriers or biocompatible materials may be used in combination of at least two thereof. The biocompatible material or carrier includes a biocompatible material that extends the *in vivo* half life through a covalent or non-covalent bond.

In the present invention, the methods in which the biocompatible material or the carrier are linked to the GLP-1/glucagon receptor dual agonist include a genetic recombination method and an *in vitro* linkage using polymers or low molecular chemicals, but are not limited thereto. The FcRn binding material may be an immunoglobulin Fc region. For example, when polyethylene glycol is used as the carrier, there may be included a Recode technique by Ambrx

Inc., which can attach position-specifically to polyethylene glycol. The methods may include a glycopegylation technique by Neose company which can attach specifically to the glycosylated moiety. Furthermore, the methods may include a releasable PEG technique in which polyethylene glycol is removed, but is not limited thereto. The methods may include techniques which can increase bioavailability using PEG. In addition, polymers such as polyethylene glycol, polypropylene glycol, ethylene glycol-propylene glycol copolymer, polyoxyethylated polyol, polyvinyl alcohol, polysaccharides, dextran, polyvinyl ethyl ether, biodegradable polymer, lipid polymer, chitins, or hyaluronic acid may be included.

When albumin is used as a carrier, the methods may include a technology in which albumins or albumin fragments can be directly covalently linked to peptides of the GLP-1/glucagon receptor dual agonist to increase the *in vivo* stability. Even if albumin is not directly linked, there may be included a technique in which the albumin binding materials, for example, albumin-specific binding antibody or an antibody fragment are bound to the peptides to bind to the albumin, and a technique in which a certain peptide/protein having a binding affinity to albumin is bound to the peptides. In addition, the methods may include a technique in which a fatty acid, etc., having a binding affinity to albumin is bound to the peptides, but is not limited thereto. Any technique or binding method which can increase the *in vivo* stability using albumin may be included herein.

The technique for binding to the peptide by using the antibody or antibody fragment as a carrier in order to increase the *in vivo* half-life may also be included in the present invention. The antibody or antibody fragment having a FcRn binding site can be used, and any antibody fragment not containing FcRn binding site such as Fab can be used. CovX-body technique of CovX company using a catalytic antibody may be included herein, and the technique which increases the *in vivo* half-life using Fc fragments may be included in the present invention. When

using the Fc fragment, the linker binding to the Fc fragment and the peptide and its binding method may include a peptide bond or a polyethylene glycol or the like, but is not limited to thereto and any chemical binding method may be applicable. In addition, the binding ratio of the GLP-1/glucagon receptor agonists dual agonist of the present invention may be 1:1 or 1:2, but is not limited thereto, and any ratio which can increase the *in vivo* half-life may be included without limitation.

Further, the carrier which is used to increase the in vivo half-life may be a non-peptidyl material such as a polysaccharide or a fatty acid.

The linker binding to the carrier which is used to increase the *in vivo* half-life may include peptides, polyethylene glycols, fatty acids, sugars, polymers, low molecular compounds, nucleotides, and a combination thereof, and may be any chemical bond such as a non-covalent chemical bond, a covalent chemical bond, etc., without limitation.

The formulation which can increase the bioavailability or continuously maintain the activity may include a sustained release formulation by microparticles, nanoparticles and the like using PLGA, hyaluronic acid, chitosan, etc.

Furthermore, the formulation of different aspects which can increase the bioavailability or continuously maintain the activity may be a formulation such as implants, inhalants, transnasal formulations or patches.

In one exemplary embodiment of the invention, examples of the GLP-1/glucagon receptor dual agonist can include a native GLP-1/glucagon receptor dual agonist such as oxyntomodulin and the derivatives thereof, the long-acting formulation thereof, and the like can also be included.

As used herein, the term "oxyntomodulin" means a peptide derived from a glucagon precursor, pre-glucagon, and includes a native oxyntomodulin, precursors, derivatives, fragments

thereof, and variants thereof. Preferably, it can have the amino acid sequence of SEQ ID NO. 1(HSQGTFTSDYSKYLDSRRAQDFVQWLMNTKRNRNNIA).

The term, “oxyntomodulin variant” is a peptide having one or more amino acid sequences different from those of native oxyntomodulin, and means a peptide that retains the function of activating the GLP-1 and glucagon receptors, and it may be prepared by any one of substitution, addition, deletion, and modification or by a combination thereof in a part of the amino acid sequences of the native oxyntomodulin.

The term, "oxyntomodulin derivative" includes peptides, peptide derivatives or peptide mimetics that are prepared by addition, deletion or substitution of amino acids of oxyntomodulin so as to activate both of the GLP-1 receptor and the glucagon receptor at a high level, compared to the native oxyntomodulin. Preferably, the oxyntomodulin derivative has an amino acid sequence of SEQ ID No. 25 and more preferably, its 16^{th} and 20^{th} amino acids form a ring.

The term, "oxyntomodulin fragment" means a fragment having one or more amino acids added or deleted at the N-terminus or the C-terminus of the native oxyntomodulin, in which non-naturally occurring amino acids (for example, D-type amino acid) can be added, and has a function of activating both of the GLP-1 receptor and the glucagon receptor.

Each of the preparation methods for the variants, derivatives, and fragments of oxyntomodulin can be used individually or in combination. For example, the present invention includes a peptide that has one or more amino acids different from those of native peptide and deamination of the N-terminal amino acid residue, and has a function of activating both of the GLP-1 receptor and the glucagon receptor.

The C-terminal of the variants, derivatives, and fragments of oxyntomodulin of the present invention may be amidated.

The carrier material which may be used in the present invention may be selected from the

group consisting of an antibody, an immunoglobulin Fc region, an albumin, a fatty acid, a carbohydrate, a polymer having a repeating unit of a peptide, a transferrin, and a PEG, and preferably an immunoglobulin Fc region. In one exemplary embodiment of the present invention, the long-acting GLP-1/glucagon receptor dual agonist is linked to a carrier by the non-peptidyl polymer as a linker. In one more exemplary embodiment, a carrier linked to a non-peptidyl polymer is an immunoglobulin Fc fragment.

In the present invention, the long-acting GLP-1/glucagon receptor dual agonist is a form in which the GLP-1/glucagon receptor dual agonist is each linked to an immunoglobulin Fc region, and shows the sustainability and safety. Binding of the immunoglobulin Fc region and the GLP-1/glucagon receptor dual agonist may be an inframe fusion without a linker or may be linked using a non-peptide polymer linker. In the present invention, the immunoglobulin Fc may be used interchangeably with immunoglobulin fragments.

As used herein, the term "non-peptidyl polymer" refers to a biocompatible polymer including at least two repeating units linked to each other by any covalent bond excluding a peptide bond. In the present invention, the non-peptidyl polymer may be interchangeably used with the non-peptidyl linker.

The non-peptidyl polymer that may be used in the present invention may be selected from the group consisting of a biodegradable polymer such as polyethylene glycol, polypropylene glycol, ethylene glycol-propylene glycol copolymer, polyoxyethylated polyol, polyvinyl alcohol, polysaccharide, dextran, polyvinyl ethyl ether, polylactic acid (PLA) or polylactic-glycolic acid (PLGA), a lipid polymer, chitin, hyaluronic acid, and a combination thereof, and preferably, the biodegradable polymer is polyethylene glycol. In addition, derivatives thereof known in the art and derivatives easily prepared by a method known in the art may be included in the scope of the present invention.

The peptide linker which is used in the fusion protein obtained by a conventional inframe fusion method has a disadvantage in that it is easily cleaved *in vivo* by a protease, and thus a sufficient effect of increasing the serum half-life of the active drug by a carrier cannot be obtained as expected. However, in the present invention, the polymer having resistance to the protease may be used to maintain the serum half-life of a peptide similarly as the carrier. Therefore, any non-peptidyl polymer may be used without limitation, as long as it is a polymer having the mentioned function, that is, a polymer having resistance to the *in vivo* protease. The non-peptidyl polymer has a molecular weight in the range of 1 to 100 kDa, and preferably of 1 to 20 kDa. Further, the non-peptidyl polymer of the present invention, linked to the immunoglobulin Fc region, may be one polymer or a combination of different types of polymers.

The non-peptidyl polymer used in the present invention has a reactive group capable of binding to the immunoglobulin Fc region and protein drug. The reactive group at both ends of the non-peptidyl polymeris preferably selected from the group consisting of a reactive aldehyde group, a propionaldehyde, a butyraldehyde group, a maleimide group, and a succinimide derivative. The succinimide derivative may be succinimidyl propionate, hydroxy succinimidyl, succinimidyl carboxymethyl, or succinimidyl carbonate. In particular, when the non-peptidyl polymer has a reactive group of the reactive aldehyde group at both ends thereof, it is effective to minimize nonspecific reactions and link a physiologically active polypeptide and an immunoglobulin at both ends of the non-peptidyl polymer. A final product produced by reductive alkylation by an aldehyde bond is much more stable than that linked by an amide bond. The aldehyde reactive group selectively binds to an N-terminus at a low pH, and binds to a lysine residue to form a covalent bond at a high pH, such as pH 9.0. The reactive groups at both ends of the non-peptidyl polymer may be the same or different from each other. For example, the non-peptidyl polymer may possess a maleimide group at one end, and an aldehyde group, a

propionaldehyde group, or a butyraldehyde group at the other end. When a polyethylene glycol having a reactive hydroxy group at both ends is used as the non-peptidyl polymer, the hydroxy group may be activated to various reactive groups by known chemical reactions, or a commercially available polyethylene glycol having a modified reactive group may be used to prepare the long acting GLP-1/glucagon receptor dual agonist conjugate of the present invention.

In addition, the immunoglobulin Fc region is advantageous in terms of the preparation, purification, and yield of the conjugate, because not only the molecular weight is relatively small compared to the entire molecule, but the homogeneity of the materials is also greatly increased and the potential of inducing antigenicity in blood is lowered, because the amino acid sequences are different in each antibody, and thus the Fab portion showing a high non-homogeneity is removed.

As used herein, the term "immunoglobulin Fc region" refers to the heavy-chain constant region 2 (CH2) and the heavy-chain constant region 3 (CH3) of an immunoglobulin, excluding the variable regions of the heavy and light chains, the heavy-chain constant region 1 (CH1), and the light-chain constant region 1 (CL1) of the immunoglobulin. It may further include a hinge region at the heavy-chain constant region. Also, the immunoglobulin Fc region of the present invention may contain a part or all of the Fc region including the heavy-chain constant region 1 (CH1) and/or the light-chain constant region 1 (CL1), except for the variable regions of the heavy and light chains of the immunoglobulin, as long as it has an effect substantially equivalent to or better than the native protein. Furthermore, the immunoglobulin Fc region may be a fragment having a deletion of a relatively long portion of the amino acid sequence which corresponds to CH2 and/or CH3. That is, the immunoglobulin Fc region of the present invention may comprise 1) a CH1 domain, a CH2 domain, a CH3 domain, and a CH4 domain, 2) a CH1 domain and a CH2 domain, 3) a CH1 domain and a CH3 domain, 4) a CH2 domain and a CH3 domain, 5) a combination of one or more domains and an immunoglobulin hinge region (or a

portion of the hinge region), and 6) a dimer of each domain of the heavy-chain constant regions and the light-chain constant region.

Further, the immunoglobulin Fc region of the present invention includes a native amino acid sequence as well as a sequence derivative (mutant) thereof. An amino acid sequence derivative has a different sequence due to a deletion, an insertion, a non-conservative or conservative substitution, or combinations thereof of one or more amino acid residues of the native amino acid sequences. For example, in an IgG Fc, amino acid residues at positions 214 to 238, 297 to 299, 318 to 322, or 327 to 331, known to be important in binding , may be used as a suitable target for modification.

Further, various kinds of derivatives are possible, including one in which a region capable of forming a disulfide bond is deleted, certain amino acid residues are eliminated at the N-terminal end of a native Fc, a methionine residue is added to the N-terminal end of a native Fc, etc. Further, to remove effector functions, a complement-binding site, such as a Clq-binding site, and an antibody dependent cell mediated cytotoxicity (ADCC) site may be deleted. Techniques of preparing such sequence derivatives of the immunoglobulin Fc region are disclosed in International Publication Nos: WO 97/34631, WO 96/32478, etc. Amino acid exchanges in proteins and peptides, which do not entirely alter the activity of the molecules, are known in the art (H. Neurath, R. L. Hill, The Proteins, Academic Press, New York, 1979). The most commonly occurring exchanges are Ala/Ser, Val/Ile, Asp/Glu, Thr/Ser, Ala/Gly, Ala/Thr, Ser/Asn, Ala/Val, Ser/Gly, Thy/Phe, Ala/Pro, Lys/Arg, Asp/Asn, Leu/Ile, Leu/Val, Ala/Glu, and Asp/Gly, in both directions. In addition, the Fc region, if desired, may be modified by phosphorylation, sulfation, acrylation, glycosylation, methylation, farnesylation, acetylation, amidation, and the like.

The Fc derivatives are derivatives that have a biological activity identical to the Fc region of the present invention, with improved structural stability of the Fc region, for example, against

heat, pH or the like.

Furthermore, these Fc regions may be obtained from native forms isolated from humans and other animals including cows, goats, pigs, mice, rabbits, hamsters, rats, guinea pigs, etc., or may be recombinants or derivatives thereof, obtained from transformed animal cells or microorganisms. Herein, they may be obtained from a native form by isolating whole immunoglobulins from human or animal organisms and then treating them with a protease. When papain is treated, papain digests the native immunoglobulin into Fab and Fc regions, and when pepsin is treated, the native immunoglobulin is cut into pF'c and F(ab)2. Fc or pF'c may be isolated by size exclusion chromatography, etc. Preferably, a human-derived Fc region is a recombinant immunoglobulin Fc region that is obtained from a microorganism.

In addition, the immunoglobulin Fc region may be in the form of having native sugar chains, or increased or decreased sugar chains compared to a native form, or may be in a deglycosylated form. The increase, decrease, or removal of the immunoglobulin Fc sugar chains may be achieved by methods common in the art, such as a chemical method, an enzymatic method and a genetic engineering method using a microorganism. The removal of sugar chains from an Fc region results in a remarkable decrease in binding affinity to the C1q part and a decrease or loss in antibody-dependent cell-mediated cytotoxicity or complement-dependent cytotoxicity, thereby not inducing unnecessary immune responses in-vivo. In this regard, an immunoglobulin Fc region in a deglycosylated or aglycosylated form may be more suitable for the objective of the present invention as a drug carrier.

As used herein, the term "deglycosylation" refers to enzymatically removing sugar moieties from an Fc region, and the term "aglycosylation" refers to an Fc region which is produced in a prokaryote, preferably E. coli, and is not glycosylated.

Meanwhile, the immunoglobulin Fc region may be derived from humans or other animals

including cows, goats, pigs, mice, rabbits, hamsters, rats, guinea pigs, etc., and preferably from humans.

Also, the immunoglobulin Fc region may be an Fc region that is derived from IgG, IgA, IgD, IgE and IgM, a combination thereof, or hybrids thereof. Preferably, it is derived from IgG or IgM which are the most abundant in human blood, and most preferably from IgG, which is known to enhance the half-lives of ligand-binding proteins, but is not limited thereto.

As used herein, the term "combination" refers to that polypeptides encoding single-chain immunoglobulin Fc regions of the same origin are linked to a single-chain polypeptide of a different origin to form a dimer or multimer. That is, a dimer or multimer may be formed from two or more fragments selected from the group consisting of IgG Fc, IgA Fc, IgM Fc, IgD Fc, and IgE Fc fragments.

As used herein, the term "hybrid" refers to that a sequence corresponding to at least two Fc fragments of a different origin is present in a single-chain immunoglobulin Fc region. In the present invention, various types of hybrid are possible. That is, the hybrid consisting of 1 to 4 domains selected from the group consisting of CH1, CH2, CH3 and CH4 of IgG Fc, IgM Fc, IgA Fc, IgE Fc and IgD Fc is possible, and may include a hinge.

On the other hand, IgG may also be classified into IgG1, IgG2, IgG3, and IgG4 sub-classes, and in the present invention, a combination or hybridization thereof is possible. It is preferably IgG2 and IgG4 sub-classes, and most preferably is a Fc region of IgG4 that substantially does not have an effector function such as a complement dependent cytotoxicity (CDC).

That is, the immunoglobulin Fc region for the carrier of the drug of the present invention may be, for example, human IgG4-derived aglycosylated Fc region, but is not limited thereto. The human-derived Fc region is preferred over nonhuman-derived Fc region which can cause undesirable immune responses, for example, which can act as an antigen in the human body to

produce a new antibody.

The method for preparing a long-acting GLP-1/glucagon receptor dual agonist of the present invention is not particularly limited. For example, details of the preparation method and its effects are described, for example, in Korean Patent Application Publication No. 10-2012-0139579.

Using the long-acting GLP-1/glucagon receptor dual agonist has huge advantages of that the number of administration to a chronic patient who needs daily administration can be dramatically reduced due to an increase in the blood half-life and *in vivo* sustainability, thereby improving the quality of life of the patient. Therefore, this is very helpful in the treatment of non-alcoholic fatty liver disease.

As used herein, the term "non-alcoholic fatty liver disease" refers to fatty liver cases in which there is no history of alcohol consumption or in which alcohol consumption is not related to the occurrence. The fatty liver refers to a phenomenon in which there is abnormal accumulation of triglyceride in liver cells, compared to normal levels of triglyceride. About 5% of normal liver consists of fat tissue and the main components of the fat are triglycerides, fatty acids, phospholipids, cholesterols, and cholesterol esters. However, once the fatty liver occurs, most of the components are replaced with triglyceride. If the amount of triglycerides is more than 5% of the liver weight, it is diagnosed as fatty liver. The fatty liver is caused by a lipid metabolism disorder or a defect in the process of carrying excessive fat in the liver cells, and is mainly caused by disorders of lipid metabolism in the liver. Most of the fat accumulated in the fatty liver may be a triglyceride. The non-alcoholic fatty liver disease includes non-alcoholic fatty liver, nonalcoholic steatohepatitis, cirrhosis, liver cancer, and the like, but the fatty liver disease to be prevented or treated with the composition of the present invention is included without limitation.

As used herein, the term "prevention" refers to all of the actions by which the

non-alcoholic fatty liver disease is prevented or delayed by administration of the composition of the present invention. The "treatment" refers to all of the actions by which the symptoms of the non-alcoholic fatty liver disease are alleviated, or positively changed. The treatment of the non-alcoholic fatty liver disease is applicable to any mammal that may experience the non-alcoholic fatty liver disease, and examples thereof include not only humans and primates, but also cattle such as cow, pig, sheep, horse, dog and cat, without limitation, but is preferably a human.

As used herein, the term "administration" refers to introduction of an amount of a predetermined substance to a patient by a suitable method. The composition of the present invention may be administered via any of the common routes, as long as it is able to reach a desired tissue. For example, it may be intraperitoneal, intravenous, intramuscular, subcutaneous, intradermal, oral, topical, intranasal, intrapulmonary, or intrarectal administration, but is not limited thereto. However, since peptides are digested upon oral administration, active ingredients of a composition for oral administration should be coated or formulated for protection against degradation in the stomach. Preferably, the composition may be administered in the form of injections. In addition, the long-acting formulation may be administered by any apparatus in which an active material can be transported into a target cell.

The administration dose and frequency of the pharmaceutical composition of the present invention are determined by the type of active ingredient, together with various factors such as the disease to be treated, administration route, patient's age, gender, and body weight, and disease severity.

The pharmaceutical composition of the present invention may further include a pharmaceutically acceptable carrier, excipient, or diluent. As used herein, the term "pharmaceutically acceptable carrier" refers to a carrier or a diluent that does not stimulate the organism and inhibit biological activity or characteristics of an administered compound. For oral

administration, the carrier may include a binder, a lubricant, a disintegrant, an excipient, a solubilizer, a dispersing agent, a stabilizer, a suspending agent, a colorant, and a flavoring agent. For injectable preparations, the carrier may include a buffering agent, a preserving agent, an analgesic, a solubilizer, an isotonic agent, a stabilizer, etc. For preparations for topical administration, the carrier may include a base, an excipient, a lubricant, a preserving agent, etc.

The composition of the present invention may be formulated into a variety of dosage forms in combination with the aforementioned pharmaceutically acceptable carriers. For example, for oral administration, the pharmaceutical composition may be formulated into tablets, troches, capsules, elixirs, suspensions, syrups or wafers. For injectable preparations, the pharmaceutical composition may be formulated into an ampule as a single dosage form or a multidose container. The pharmaceutical composition may also be formulated into solutions, suspensions, tablets, pills, capsules and long-acting preparations.

On the other hand, examples of the carrier, the excipient, and the diluent suitable for the pharmaceutical formulations include lactose, dextrose, sucrose, sorbitol, mannitol, xylitol, erythritol, maltitol, starch, acacia rubber, alginate, gelatin, calciumphosphate, calcium silicate, cellulose, methylcellulose, microcrystalline cellulose, polyvinylpyrrolidone, water, methylhydroxybenzoate, propylhydroxybenzoate, talc, magnesium stearate and mineral oils. In addition, the pharmaceutical formulations may further include fillers, anti-coagulating agents, lubricants, humectants, flavorants, and antiseptics.

In another aspect, the present invention provides a method for preventing or treating a non-alcoholic liver disease, comprising a step of administering the composition comprising the long-acting GLP-1/glucagon receptor dual agonist to a subject, exclusive of humans, at high risk of or having the non-alcoholic liver disease.

The description of the composition and non-alcoholic fatty liver disease is the same as above.

【Mode for Invention】

Hereinafter, the present invention will be described in more detail by way of examples. These examples are only intended to illustrate the present invention, and the scope of the present invention is not construed as being limited to these examples.

Example 1 : Synthesis of oxyntomodulin derivatives

In the examples, oxyntomodulin derivatives having the following amino acid sequences were synthesized (Table 1).

【Table 1】

SEQ ID NO	Sequence	Note
SEQ ID NO: 1	HSQGTFTSDYSKYLDSRRAQDFVQWLMNTKRNRNNIA	
SEQ ID NO: 2	CA-SQGTFTSDYSKYLDEEAVRLFIEWLMNTKRNRNNIA	
SEQ ID NO: 3	CA-SQGTFTSDYSKYLDERRAQDFVAWLKNTGPSSGAPPPS	
SEQ ID NO: 4	CA-GQGTFTSDYSRYLEEEAVRLFIEWLKNGGPSSGAPPPS	
SEQ ID NO: 5	CA-GQGTFTSDYSRQMEEEAVRLFIEWLKNGGPS	

	SGAPPPS	
SEQ ID NO: 6	CA-GEGTFTSDLSRQMEEEAVRLFIEWAAHSQGTFTSDYSKYLD	
SEQ ID NO: 7	CA-SQGTFTSDYSRYLDEEAVRLFIEWLMNTK	
SEQ ID NO: 8	CA-SQGTFTSDLSRQLEEEAVRLFIEWLMNK	
SEQ ID NO: 9	CA-GQGTFTSDYSRYLDEEAVXLFIEWLMNTKRNRNNIA	
SEQ ID NO: 10	CA-SQGTFTSDYSRQMEEEAVRLFIEWLMNGGPSSGAPPPSK	
SEQ ID NO: 11	CA-GEGTFTSDLSRQMEEEAVRLFIEWAAHSQGTFTSDYSRYLDK	
SEQ ID NO: 12	CA-SQGTFTSDYSRYLDGGGHGEGTFTSDLSKQMEEEAVK	
SEQ ID NO: 13	CA-SQGTFTSDYSRYLDXEAVXLFIEWLMNTK	
SEQ ID NO: 14	CA-GQGTFTSDYSRYLDEEAVXLFIXWLMNTKRNRNNIA	
SEQ ID NO: 15	CA-GQGTFTSDYSRYLDEEAVRLFIXWLMNTKRNRNNIA	
SEQ ID NO: 16	CA-SQGTFTSDLSRQLEGGGHSQGTFTSDLSRQLEK	
SEQ ID NO: 17	CA-SQGTFTSDYSRYLDEEAVRLFIEWIRNTKRNRNNIA	
SEQ ID NO: 18	CA-SQGTFTSDYSRYLDEEAVRLFIEWIRNGGPSSGAPPPSK	

SEQ ID NO: 19	CA-SQGTFTSDYSRYLD**E**EAV**K**LFIEWIRNTKRN RNNIA	Ring Formation
SEQ ID NO: 20	CA-SQGTFTSDYSRYLD**E**EAV**K**LFIEWIRNGGPS SGAPPPSK	Ring Formation
SEQ ID NO: 21	CA-SQGTFTSDYSRQLEEEAVRLFIEWVRNTKRN RNNIA	
SEQ ID NO: 22	DA-SQGTFTSDYSKYLD**E**KRA**K**EFVQWLMNTK	Ring Formation
SEQ ID NO: 23	HAibQGTFTSDYSKYLDEKRAKEFVCWLMNT	
SEQ ID NO: 24	HAibQGTFTSDY SKYLDEKRAK EFVQWLMNTC	
SEQ ID NO: 25	HAibQGTFTSDYSKYLD**E**KRA**K**EFVQWLMNTC	Ring Formation
SEQ ID NO: 26	HAibQGTFTSDYS**K**YLD**E**KRAKEFVQWLMNTC	Ring Formation
SEQ ID NO: 27	HAibQGTFTSDYSKYLD**E**QAA**K**EFICWLMNT	Ring Formation
SEQ ID NO: 28	HAibQGTFTSDY SKYLDEKRAK EFVQWLMNT	
SEQ ID NO: 29	H(d)SQGTFTSDYSKYLDSRRAQDFVQWLMNTK RNRNNIA	
SEQ ID NO: 30	CA-SQGTFTSDYSKYLDSRRAQDFVQWLMNTKR NRNNIA	
SEQ ID NO: 31	CA-(d)SQGTFTSDYSKYLDSRRAQDFVQWLMNT KRNRNNIA	
SEQ ID NO: 32	CA-AibQGTFTSDYSKYLD**E**KRA**K**EFVQWLMNT C	Ring Formation
SEQ ID NO: 33	HAibQGTFTSDYAKYLD**E**KRA**K**EFVQWLMNTC	Ring Formation
SEQ ID NO: 34	YAibQGTFTSDYSKYLD**E**KRA**K**EFVQWLMNTC	Ring Formation

In Table 1, amino acids in bold and underlined in each of SEQ ID NOS: 19, 20, 22, 25, 26, 27, 32, 33, and 34, taken together, form a ring, and amino acids represented by X mean a non-native amino acid, alpha-methyl-glutamic acid. In addition, CA represents 4-imidazoacetyl, and DA represents desamino-histidyl.

Hereafter, a representative long-acting GLP-1/glucagon receptor dual agonist, i.e., the long-acting GLP-1/glucagon receptor dual agonist in which Fc is linked to the 30th amino acid of the GLP-1/glucagon receptor dual agonist by the non-peptidyl polymer, PEG (polyethylene glycol), was prepared and used in Examples 2 to 3 below.

Example 2 : Confirmation of the effects of the long-acting GLP-1/glucagon receptor dual agonist on non-alcoholic fatty liver disease in the high-fat, fructose and cholesterol containing high trans-fat feed intake ob/ob mouse model

In order to confirm the effects of the long-acting GLP-1/glucagon receptor dual agonist on non-alcoholic fatty liver disease, a high-fat (40% kcal), fructose(22%) and cholesterol (2%)-containing high trans-fat diet (HTF diet) was taken to administrated to ob/ob mouse model for 8 weeks to prepare an animal model for non-alcoholic fatty liver disease. Then, the long-acting GLP-1/glucagon receptor dual agonist was subcutaneously administered to the mouse once every two days (Q2D) with 0.7 and 1.4 nmol/kg and the administration was repeated for 4 weeks. The weight of the animals was compared to that of the vehicle-treated group during the 4-week test. After completion of the 4 week-test, the liver weights were measured and compared. Further, after completion of the 4 week-test, mRNAs of, collagen-1a which is a fibrosis marker; TNF-α which is a pro-inflammatory marker; and SREBP-1c which is a lipogenesis marker were confirmed.

As a result, the measurement of the body weight and the liver weight after administration for 4 weeks has shown that, in the long-acting GLP-1/glucagon receptor dual agonist, the weight was significantly reduced as compared to that of vehicle-treated group (Fig. 1). Such results suggest that the long-acting GLP-1/glucagon receptor dual agonist of the present invention can suppress the weight gain which occurs in the animal model for non-alcoholic fatty liver disease and that it can reduce the side-effects of conventional drugs for improving insulin resistance.

Further, the comparison of mRNA of collagen-1a, TNF-α, SREBP-1c has shown that in the long-acting GLP-1/glucagon receptor dual agonist-treated group, these mRNA were significantly reduced (Fig. 2). Such results suggest that the long-acting GLP-1/glucagon receptor dual agonist of the present invention reduces fibrosis, pro-inflammation and the like in the animal model for the non-alcoholic fatty liver disease and inhibit fat production, thus being effective for the prevention and treatment of non-alcoholic fatty liver disease.

Example 3 : Confirmation of the effects of the long-acting GLP-1/glucagon receptor dual agonist on non-alcoholic fatty liver disease in the high trans-fat feed intake DI0 mouse model

In order to confirm the effects of the long-acting GLP-1/glucagon receptor dual agonist on the non-alcoholic fatty liver disease, a 60% high trans-fat diet was administered to normal mouse model(C57BL/6) for 12 weeks to prepare an animal model for non-alcoholic fatty liver disease. Then, 3nmol/kg of the long-acting GLP-1/glucagon receptor dual agonist was subcutaneously administered to the mouse once every week (QW) and the administration was repeated for 4 weeks. After completion of the 4 week-test, hepatic triglyceride (hepatic TG) and serum cholesterol were measured.

As a result, the measurement of the hepatic triglycerides and serum cholesterol after

administration for 4 weeks has shown that, in the case of administration of the long-acting GLP-1/glucagon receptor dual agonist, they were significantly reduced as compared to those of the vehicle-treated group and also that they were significantly reduced to the level of a normal animal which has undergone a chow diet (Fig. 3). Such results suggest that the long-acting GLP-1/glucagon receptor dual agonist of the present invention can reduce the hepatic triglyceride and serum cholesterol to normal animal levels in the animal model for the non-alcoholic fatty liver disease, thus being effective for the prevention and treatment of non-alcoholic fatty liver disease.

From the above description, a person skilled in the art will appreciate that the invention may be embodied in other specific forms without changing the technical spirit or essential characteristics. In this regard, the embodiments described above should be understood to be illustrative rather than restrictive in every respect. The scope of the invention should be construed that the meaning and scope of the appended claims rather than the detailed description and all changes or variations derived from the equivalent concepts fall within the scope of the present invention.

Claims

1. A use of a long-acting glucagon-like peptide-1 (GLP-1)/glucagon receptor dual agonist conjugate in the manufacture of a medicament for the prevention and/or treatment of liver inflammation by reducing the expression or activity of tumor necrosis factor-α (TNF-α), wherein the conjugate comprises:

a GLP-1/glucagon receptor dual agonist comprising the amino acid sequence of any one of SEQ ID NOs: 24, 25, or 26,

an immunoglobulin Fc region, and

a non-peptidyl polymer, wherein the non-peptidyl polymer covalently links the GLP-1/glucagon receptor dual agonist and the immunoglobulin Fc region.

2. The use according to claim 1, wherein the conjugate has no side effect of weight gain or reduces the side effect of weight gain.

3. The use according to claim 1 or 2, wherein the conjugate further performs at least one of the following features:

a) reducing the expression or activity of collagen-1a, which is a fibrosis marker;

b) reducing the expression or activity of sterol regulatory element binding protein-1c (SREBP-1c), which is a lipogenesis marker;

c) reducing liver triglycerides; and

d) reducing blood cholesterol.

4. The use according to any one of the previous claims, wherein the conjugate simultaneously activates the GLP-1 receptor and the glucagon receptor.

5. The use according to any one of the previous claims, wherein the GLP-/glucagon receptor dual agonist comprises the amino acid sequence of SEQ ID NO: 24.

6. The use according to any one of the previous claims, wherein the amino acids at positions 12 and 16 or 16 and 20 form a ring.

7. The use according to claim 6, wherein the GLP-1/glucagon receptor dual agonist comprises the amino acid sequence of SEQ ID NO: 25.

8. The use according to claim 6, wherein the GLP-1/glucagon receptor dual agonist comprises the amino acid sequence of SEQ ID NO: 26.

9. The use according to any one of the previous claims, wherein the non-peptidyl polymer comprises polyethylene glycol, polypropylene glycol, an ethylene glycol-propylene glycol

copolymer, a polyoxyethylated polyol, polyvinyl alcohol, a polysaccharide, polyvinyl ethyl ether, a biodegradable polymer, a lipid polymer, hyaluronic acid, or a combination thereof.

10. The use according to claim 9, wherein the non-peptidyl polymer is polyethylene glycol.

11. The use according to claim 9, wherein the polysaccharide is dextran, a chitin, or a combination thereof.

12. The use according to any one of the previous claims, wherein the immunoglobulin Fc region is aglycosylated.

13. The use according to any one of the previous claims, wherein the immunoglobulin Fc region comprises one to four domains of CH1, CH2, CH3, or CH4 domains.

14. The use according to claim 13, wherein the immunoglobulin Fc region further comprises a hinge region.

15. The use according to any one of the previous claims, wherein the immunoglobulin Fc region is derived from IgG, IgA, IgD, IgE, or IgM.

16. The use according to any one of the previous claims, wherein the immunoglobulin Fc region is a hybrid of domains from IgG, IgA, IgD, IgE, or IgM.

17. The use according to any one of the previous claims, wherein the immunoglobulin Fc region is a dimer or polymer consisting of single chain immunoglobulins comprising domains having the same origin.

18. The use according to any one of the previous claims, wherein the liver inflammation is caused by at least one disease selected from the group consisting of non-alcoholic fatty liver, non-alcoholic steatohepatitis, cirrhosis, and liver cancer.