



(86) Date de dépôt PCT/PCT Filing Date: 2009/11/06
 (87) Date publication PCT/PCT Publication Date: 2010/05/14
 (45) Date de délivrance/Issue Date: 2017/05/23
 (85) Entrée phase nationale/National Entry: 2011/05/06
 (86) N° demande PCT/PCT Application No.: US 2009/063469
 (87) N° publication PCT/PCT Publication No.: 2010/054135
 (30) Priorité/Priority: 2008/11/07 (US12/267,208)

(51) Cl.Int./Int.Cl. *A61K 31/38* (2006.01),
A61K 31/19 (2006.01), *A61P 27/02* (2006.01)
 (72) Inventeurs/Inventors:
GARNER, WILLIAM, US;
GARNER, MARGARET, US
 (73) Propriétaire/Owner:
ENCORE HEALTH, LLC, US
 (74) Agent: BORDEN LADNER GERVAIS LLP

(54) Titre : EMPLOI DE FAIBLES DOSES D'ACIDE LIPOIQUE DANS LE TRAITEMENT DES TROUBLES OCULAIRES
 (54) Title: USE OF LOW DOSAGES OF LIPOIC ACID IN THE TREATMENT OF OCULAR DISORDERS

(57) **Abrégé/Abstract:**

The invention relates to compositions comprising doses of lipoic acid-based compounds, and uses for same. The compositions provided by the present invention comprise 10 µM to 250 µM of lipoic acid, lipoic acid derivatives, and/or lipoic acid seleno-derivatives, and are used for preventing or treating oxidation damage to ocular cells, decreasing elasticity of a human lens, and/or treating or preventing presbyopia. The compound can be 5-(1,2-dithiolan-3-yl)pentanoic acid, 6,8-dimercaptooctanoic acid, dihydrolipoate, 5-(1,2-thiaselenolan-5-yl)pentanoic acid, 5-(1,2-thiaselenolan-3-yl)pentanoic acid, or a salt or ester thereof.

Abstract

The invention relates to compositions comprising doses of lipoic acid-based compounds, and uses for same. The compositions provided by the present invention comprise 10 μ M to 250 μ M of lipoic acid, lipoic acid derivatives, and/or lipoic acid seleno-derivatives, and are used for preventing or treating oxidation damage to ocular cells, decreasing elasticity of a human lens, and/or treating or preventing presbyopia. The compound can be 5-(1,2-dithiolan-3-yl)pentanoic acid, 6,8-dimercaptooctanoic acid, dihydrolipoate, 5-(1,2-thiaselenolan-5-yl)pentanoic acid, 5-(1,2-thiaselenolan-3-yl)pentanoic acid, or a salt or ester thereof.

USE OF LOW DOSAGES OF LIPOIC ACID IN THE TREATMENT OF OCULAR DISORDERS

[0001]

5

BACKGROUND OF THE INVENTION

[0002] As we age, our lenses undergo physiological changes that make it more difficult to
10 focus on near objects. That is why nearly everyone requires reading glasses, even as early as
age 35-40. The ability of the eye to change focal power, also known as accommodative
amplitude, decreases significantly with age. The accommodative amplitude is 20 diopters in
children and young adults, but it decreases to 10 diopters by age 25 and to ≤ 1 diopter by age
60. The age-related inability to focus on near objects is called presbyopia. All of us will
15 develop presbyopia and will use corrective lenses unless a new treatment is found.

[0003] Both presbyopia and cataract are age-related and may share common etiologies such
as lens growth, oxidative stress, and/or disulfide bond formation.

[0004] There is a need for compositions and methods for combating presbyopia and/or
cataract, particularly compositions and methods that minimize toxicity to surrounding healthy
20 tissues.

BRIEF SUMMARY OF THE INVENTION

[0005] In one embodiment, a pharmaceutical composition for ocular use comprises a lipoic
acid-based active agent and a pharmaceutically acceptable carrier. The amount of the active
agent can be, e.g., less than about 250 μM , about 5 μM to about 250 μM , or about 10 μM to
25 about 100 μM . The pharmaceutical composition can include, e.g., an emulsifier and a
buffered carrier.

[0006] The active agent can be, e.g., any one of 5-(1,2-dithiolan-3-yl)pentanoic acid; 5-
(1,2-thiaselenolan-5-yl)pentanoic acid; dihydrolipoate; 5-(1,2-thiaselenolan-3-yl)pentanoic
acid; 6,8-dimercaptooctanoic acid; or a salt or ester thereof. The active agent can be the R
30 enantiomer.

[0007] In another embodiment, a method of preventing or treating oxidation damage to cells comprises administering the pharmaceutical composition either in vivo or in vitro. The cells can be ocular cells, e.g., lens cells. The compound can be administered via a topical ocular, subtenons, subconjunctival, intracameral, intravitreal, or iontophoresis route.

5 [0008] The method can include a step of administering a chemical energy source, e.g., glucose or NADPH, simultaneously or consecutively with the active agent. The method can include a step of applying energy, e.g., to a localized region, to facilitate breaking disulfide bonds.

[0009] The method can be used to increase or maintain accommodative amplitude, as
10 measured in diopters, to at least 2% greater than the accommodative amplitude expected in an untreated lens of about the same age. The method can increase accommodative amplitude by at least 0.25 diopters. The method can be used to increase or maintain lens elasticity, as measured in diopters or by elasticity E, to at least 2% greater than the elasticity expected in an untreated lens of about the same age. The method can be used to decrease or maintain
15 lens opacity to at least 2% less than the opacity expected in an untreated lens of about the same age.

BRIEF DESCRIPTION OF THE FIGURES

[0010] Fig. 1 depicts the accommodative amplitude in diopters (D) of an untreated human lens as a function of age in years. Borja, D et al. 2008. Optical Power of the Isolated Human
20 Crystalline Lens. Invest Ophthalmol Vis Sci 49(6):2541-8. Borja et al. calculated the maximum possible accommodative amplitude of each measured lens power data point (n = 65). As shown, there is good agreement between the age-dependent loss of accommodation and the maximum amplitude of accommodation calculated from the isolated lens power.

[0011] Fig. 2 shows a trend graph of the shear modulus versus position in the lens and age.
25 Weeber, HA et al. 2007. Stiffness gradient in the crystalline lens. Graefes Arch Clin Exp Ophthalmol 245(9):1357-66. The line at the bottom is the 20-year-old lens; the line at the top is the 70-year-old lens. The modulus increases with age for all positions in the lens. Measurements were taken up to 4.0 mm from the lens centre. The lines are extrapolated to a radius of 4.5 mm (lens diameter 9.0 mm).

30 [0012] Fig. 3 depicts the average opacity (opacimetry) of an untreated human lens as a function of age in years. Bonomi, L et al. 1990. Evaluation of the 701 interzeag lens opacity meter. Graefe's Arch Clin Exp Ophthalmol 228(5):447-9. Lens opacity was measured in 73

healthy subjects between 10 and 76 years of age without slit-lamp evidence of cataract and with a visual acuity of 20/20. These subjects were classified into ten age groups. This study was carried out using the Interzeag Opacity Meter according to the procedure described by Flammer and Bebies (Flammer J, Bebie H. 1987. Lens Opacity Meter: a new instrument to
5 quantify lens opacity. Ophthalmologica 195(2):69-72) and following the suggestions of the operating manual for the instrument.

[0013] Fig. 4 depicts a scatter plot of the change in ΔD (micrometers) in the absence (control) and presence of lipoic acid in lens organ culture experiments. The symbol ‡ designates significantly larger changes in ΔD when compared to controls. Statistical values
10 are highly significant at $p < 0.0001$ by unpaired t-test and by Kruskal Wallis test, which compared medians of each data set. The relative change in Young's modulus (E) can be calculated as the cubic value derived from the ΔD of the control divided by the ΔD of the experimental or E fractional change = $(\Delta D \text{ con}/\Delta D \text{ exp})^3$.

[0014] Fig. 5 depicts a scattergram of the percent of the total protein SH groups in disulfide
15 bonds. Free SH groups were alkylated with 4-acetamido-4'-maleimidylstilbene-2,2'-sulfonic acid (c, 1 μM , 5 μM , 9.6 μM , 50 μM , 96 μM) or 7-diethylamino-3-(4'-maleimidylphenyl)-4-methyl coumarin (500 μM , and 500 μM c). Following removal of the first alkylating agent, the S-S bonds were reduced and alkylated with fluorescein-5-maleimide. Absorption spectra were used to calculate total protein (A280 nm), free protein SH (A322 or A384), and protein
20 SS (A490) using the appropriate extinction coefficients. The symbol ‡ indicates statistically significant difference of mean with mean of control (c, $p \leq 0.05$). The symbol ** indicates means of 500 μM lipoic acid and the 500 μM control were significantly different from each other ($p = 0.027$).

DETAILED DESCRIPTION OF THE INVENTION

25 [0015] Compositions and methods are provided that can prevent, reduce, reverse, and/or slow the rate of lens growth, oxidative damage, and/or disulfide bond formation. These compositions and methods may thus effectively prevent or treat presbyopia and/or cataract.

[0016] In one embodiment, we provide a pharmaceutical composition comprising an active agent that is lipoic acid, especially alpha lipoic acid, or a derivative thereof. Preferably, the
30 active agent is a reducing agent that is capable of reducing disulfide bonds, particularly disulfide bond formation in lens membranes and membrane associated proteins.

Accordingly, particularly preferred active agents are capable of entering into the lens epithelial cells.

[0017] In one embodiment, the active agent enters the lens epithelial cells using a naturally occurring transport mechanism. For example, lipoic acid enters lens cells via specific plasma membrane symporters and antiporters. In one embodiment, the active agent is a derivative of lipoic acid that maintains the capability of utilizing the naturally occurring transport mechanism for lipoic acid.

[0018] In one embodiment, the active agent is lipoic acid, especially alpha-lipoic acid, or a derivative thereof. Lipoic acid-based active agents include, but are not limited to, 5-(1,2-dithiolan-3-yl)pentanoic acid (lipoic acid); 6,8-dimercaptooctanoic acid (dihydrolipoic acid); and dihydrolipoate.

[0019] In another embodiment, the active agent can be a seleno-substituted agent. Without being bound by theory, it is believed that including selenium in the active agent can improve redox potential compared to the same agent without selenium. The selenium derivative can thus take advantage of the intracellular redox potential of the lens. Accordingly, the active agent can be a lipoic acid derivative including selenium. In one embodiment, the active agent is a seleno-lipoic acid-based agent such as 5-(1,2-thiaselenolan-5-yl)pentanoic acid or 5-(1,2-thiaselenolan-3-yl)pentanoic acid.

[0020] In one embodiment, the active agent is 5-(1,2-dithiolan-3-yl)pentanoic acid; 6,8-dimercaptooctanoic acid; dihydrolipoate; 5-(1,2-thiaselenolan-5-yl)pentanoic acid; or 5-(1,2-thiaselenolan-3-yl)pentanoic acid. In another embodiment, the active agent is 6,8-dimercaptooctanoic acid; dihydrolipoate; 5-(1,2-thiaselenolan-5-yl)pentanoic acid; or 5-(1,2-thiaselenolan-3-yl)pentanoic acid. In another embodiment, the active agent is 6,8-dimercaptooctanoic acid or dihydrolipoate. In yet another embodiment, the active agent is 5-(1,2-dithiolan-3-yl)pentanoic acid.

[0021] The active agent can also be in a salt or ester form.

[0022] The active agent can be administered as a racemate or as an enantiomer. Lipoic acid and its derivatives are preferably administered to include the R form. Synthetic methods to yield a racemate may be less expensive than stereo-specific processes including isolation/purification steps. On the other hand, administering a single enantiomer can lower the therapeutically effective amount, thus decreasing any toxicity effects of the active agent.

[0023] As the agents described herein may have therapeutic uses as described in further detail below, it is preferable to select an active agent with low toxicity. Additional acceptable lipoic acid derivatives can be selected by in vitro toxicology testing. See Example 1.

[0024] The agents described herein can be formulated with a pharmaceutically acceptable carrier to provide pharmaceutical compositions. The pharmaceutical composition may also contain one or more excipients as is well known in the art of pharmaceutical formulary. In one embodiment, the pharmaceutical composition is formulated for ocular use. That is, the pharmaceutically acceptable carrier and/or other excipients are selected to be compatible with, and suitable for, ocular use. Such carriers and excipients are well known in the art. The excipients may also be selected and/or formulated to improve the solubility of the agent. For example, the pharmaceutical composition can include one or more of emulsifiers, buffers, salts, preservatives, lubricants, polymers, solvents, and other known excipients for ocular pharmaceutical formulations. In one embodiment, the pharmaceutical composition includes an emulsifier and a buffered carrier such as Polysorbate 80 in HBSS (Hank's Balanced Salt Solution).

[0025] The agents can also be administered with a chemical energy source, such as portion of glucose or NADPH, to facilitate reduction. The agent and chemical energy source can be co-formulated (e.g., prepared together in a single pharmaceutical formulation) or co-administered (administered simultaneously or consecutively in any order in individual formulations).

[0026] In one embodiment, the pharmaceutical composition contains a low dose of the active agent. In one embodiment, the concentration of a lipoic acid-based active agent in the pharmaceutical composition is about 0.0002 to 0.05 weight percent, more preferably about 0.0002 to 0.02, 0.001 to 0.02, or 0.002 to 0.02 weight percent. In another embodiment, the concentration of a lipoic acid-based active agent in the pharmaceutical composition is less than 0.05, 0.02, 0.01, 0.002, 0.001, or 0.0002 weight percent.

[0027] Although lipoic acid is a naturally occurring substance in the eye, and exogenous lipoic acid has been used before in various contexts, the present inventors have surprisingly found that a dramatic reduction in formulation and dosing amounts is possible with little if any effect on efficacy. For example, previous attempts to use lipoic acid to improve accommodation required concentrations of 0.05 – 0.2 weight percent (see U.S. Patent 5,817,630). However, the present inventors have discovered that the concentration may be

lowered, in some cases lowered by orders of magnitude, with little if any decrease in efficacy. This discovery has important synthesis, formulation, and toxicity implications. Regarding the synthesis, the formulation and dosing amounts may be further reduced by isolating the R enantiomer as described above. Regarding the formulation, the dosage of the lipoic acid-based active agent can be, e.g., 0.001 to 0.02 weight percent while still maintaining equal efficacy to doses of 1 mM or greater. This demonstrated efficacy in turn reduces any concomitant toxicity, thereby achieving a more desirable safety and efficacy profile. Moreover, when the active agent is used in combination with other active components, such as, e.g., a photolabile protecting group as described in the co-pending U.S. Patent Application describing caged compounds, the ability to reduce the dose of lipoic acid also reduces the dose of the accompanying protecting group. Thus, lowering the dose of the lipoic acid-based active agent achieves a reduction in toxicity for all accompanying components.

[0028] The agents described herein can be employed in a method including the step of providing a lipoic acid-based active agent to a cell, either in vitro or in vivo.

[0029] The agents described herein can be employed in a method for treating or preventing oxidation damage to cells. Such a method includes the step of administering a pharmaceutical composition comprising a lipoic acid-based active agent to a cell, either in vitro or in vivo.

[0030] As stated above, the agents can be delivered to cells in vitro or in vivo. In one embodiment, the cells are in vivo. In either case, the cells can be ocular cells, e.g., lens cells. In one embodiment, the agent is delivered to a lens, either in vitro or in vivo. Because oxidative damage has been implicated in other disorders including cancer, the agents may prove useful for administration to any type of cell exhibiting or prone to oxidative damage.

[0031] The agents can be administered to a lens by any route of administration including, but not limited to, topical ocular, subtenons, subconjunctival, intracameral, intravitreal, or iontophoresis routes. In one embodiment, the agent can be delivered topically, e.g., via an eye drop, gel, ointment, or salve. In other embodiment, the agent can be delivered via an acute delivery system, e.g., using nanotubes, local injection, micro-injection, syringe or scleral deposition, or ultrasound. The delivery systems can be adapted to delivery the agent to a target region, e.g., an area exhibiting inelasticity, opacity, and/or proliferation. In one embodiment, the agent can be localized to the anterior central portion of the lens.

[0032] The method can further include applying energy. Exemplary forms of applied energy include, but are not limited to, laser, ultrasound, tuned and focused ultrasound, particle beam, plasma beam, X-ray, ultraviolet, visible light, infrared, heat, ionizing, light, magnetic, microwave, sound, electrical, femtosecond laser, and tuned femtosecond laser.

5 Additionally or alternatively, the energy can be applied to only a localized area of the target. In some embodiment, energy is applied using an LED or laser source, which advantageously enables spatial specificity to deliver light to a localized region. Additionally or alternatively, other optical tools for creating and/or improving spatial specificity can be used with the methods described herein. The energy can be targeted to particular areas, e.g., areas
10 exhibiting inelasticity, opacity, and/or proliferation, while leaving other areas unaffected. In one embodiment, the energy can be localized to the anterior central portion of the lens. This step can be performed as previously disclosed in co-pending U.S. Publication 2008/0139990 or co-pending U.S. Patent Application describing caged compounds.

[0033] The energy can be applied within the "activation volume" to change the flexibility
15 of the lens so that the restoring force of the lens capsule is able to form the lens to a maximal spherical shape with increased curvature. The "activation volume" would be limited only by the available dilation of the patient papillary area although a smaller area may suffice to restore accommodative amplitude.

[0034] The methods preferably utilize a therapeutically effective amount of the active
20 agent. The term "therapeutically effective amount" means an amount that is capable of preventing, reducing, reversing, and/or slowing the rate of oxidative damage. For ocular applications, a therapeutically effective amount may be determined by measuring clinical outcomes including, but not limited to, the elasticity, stiffness, viscosity, density, or opacity of a lens.

25 [0035] Lens elasticity decreases with age, and is a primary diagnostic and causative factor for presbyopia. Lens elasticity can be measured as accommodative amplitude in diopters (D). Fig. 1 depicts the average elasticity in diopters of an untreated human lens as a function of age in years. The lower the value of D, the less elastic the lens. In one embodiment, the agents described herein (in the active form) can decrease and/or maintain D at a value that is
30 greater than the D value exhibited by an untreated lens of about the same age. In other words, the agents can keep accommodative amplitude "above the line" (the solid line mean accommodative amplitude) depicted in Fig. 1. In one embodiment, D is increased and/or

maintained at a value about 2, 5, 7, 10, 15, 25, 50, 100, 150, or 200 percent above the line. However, as individual lenses may differ with respect to average values, another embodiment provides any increase in accommodative amplitude, maintenance of accommodative amplitude, or reduction in the rate of decline of accommodative amplitude (i.e., reduction in the rate of decrease in diopters) for an individual lens compared to the accommodative amplitude of the same lens before treatment. Accordingly, in another embodiment, the methods provide an increase in accommodative amplitude of about 0.25 to about 8 diopters, or at least about 0.1, 0.2, 0.25, 0.5, 1, 1.2, 1.5, 1.8, 2, 2.5, 3, 5, or 8 diopters compared to the same lens before treatment.

10 [0036] Lens elasticity can also be measured by the unit of elasticity E. The higher the value of E, the less elastic the lens. Fig. 2 depicts the average elasticity (E) of an untreated human lens as a function of age in years. In one embodiment, the agents described herein (in the active form) can decrease and/or maintain E at a value that is less than the E value exhibited by an untreated lens of about the same age. In other words, the agents can keep lens elasticity "below the line" depicted in Fig. 2. In one embodiment, E is decreased and/or maintained at a value about 2, 5, 7, 10, 15, 25, 50, 100, 150, or 200 percent below the line. However, as individual lenses may differ with respect to average values, another embodiment provides any increase in elasticity, maintenance of elasticity, or reduction in the rate of decline of elasticity (i.e., reduction in the rate of increase in E value) for an individual lens compared to the elasticity of the same lens before treatment.

20 [0037] Therapeutic efficacy can also be measured in terms of lens opacity. Lens opacity increases with age and is a primary diagnostic and causative factor for cataract. Fig. 3 depicts the average opacity of an untreated human lens as a function of age in years. In one embodiment, the agents described herein (in the active form) can decrease and/or maintain opacity at a value that is less than the opacity value exhibited by an untreated lens of about the same age. In other words, the agents can keep lens opacity "below the line" depicted in Fig. 3. In one embodiment, lens elasticity is decreased and/or maintained at a value about 2, 5, 7, 10, 15, 25, 50, 100, 150, or 200 percent below the line. However, as individual lenses may differ with respect to average values, another embodiment provides any decrease, maintenance, or reduction in the rate of increase of opacity for an individual lens compared to the opacity of the same lens before treatment.

[0038] Therapeutic efficacy can also be measured as a reduction in the rate of cell proliferation, particularly lens epithelial cell proliferation. Thus, in some embodiments, therapeutic efficacy can be measured by cytostatic effect.

[0039] Some agents described herein exist naturally in the untreated eye. Lipoic acid, for example, occurs naturally in eye tissue. In general, a therapeutically effective amount of the exogenously administered agent is often at least about 1 or 2 orders of magnitude larger than the natural level of the compound. In one embodiment, the dose amount of lipoic acid or a derivative thereof is about 5 μM to about 250 μM or about 10 μM to about 100 μM . In another embodiment, the dose amount of lipoic acid or derivative thereof is no more than about 250 μM , 100 μM , 50 μM , 20 μM , 10 μM . The dose amount will depend on the route of administration as well as the age and condition of the patient. Similarly, the frequency of dosing will depend on similar factors as can be determined by one of ordinary skill in the art.

[0040] Efficacy has been demonstrated in vitro for specific exemplary dosing. (See Example 2) Fig. 2 shows that the inelasticity increases by a factor of nearly 20 during the critical period from age 40 to 55 years. From current data, a 10 μM dose can decrease the inelasticity over 95% within a millimeter volume element (voxel). Extrapolation of these results to a volume element in the human lens suggests that using this treatment dose on a 55 year old person with a 10 kPA lens starting modulus value (see Fig. 2) could be reduced after treatment to a value of about 0.5 kPA (which then corresponds to a value typically seen with a 40 yr old person). Fig. 1 permits a conversion of these modulus values to optical amplitude: accommodative amplitude is normally reduced to almost 0 above 55 years, while a person at 40-45 years still exhibits around 4-5 diopters of accommodation.

[0041] The methods include preventative methods that can be performed on patients of any age. The methods also include therapeutic methods that can be performed on patients of any age, particularly patients that are 20, 25, 30, 35, 40, 45, 50, 52, 55, 57, 60, 70, 75, or 80 years of age or older.

[0042] Any numerical values recited herein include all values from the lower value to the upper value in increments of any measurable degree of precision. For example, if the value of a variable such as age, amount, time, percent increase/decrease and the like is 1 to 90, specifically from 20 to 80, and more specifically from 30 to 70, it is intended that values such as 15 to 85, 22 to 68, 43 to 51, 30.3 to 32, etc., are expressly enumerated in this specification. In other words, all possible combinations of numerical values between the lowest value and

the highest value enumerated are to be considered to be expressly stated in this application in a similar manner.

EXAMPLES

[0043] Example 1: In vitro toxicology studies

5 **[0044]** Cell viability was determined using human umbilical vein endothelial cells (HUVEC, first passage). Cells were treated with the active agent in doses ranging from 0.1 μ M to 100 μ M. The number of live and dead cells was determined using the MultiTox-Fluor assay (Promega) or Live/Dead® assay (Invitrogen). Logistic plots were used to determine the compound's LD₅₀ value. Lipoic acid was not cytotoxic in the concentration range.

10 **[0045]** Example 2: In vitro efficacy studies

[0046] *Increase in Elasticity:* Pairs of mouse lenses were incubated in medium 200 supplemented with an antibiotic, an antimycotic, in the presence or absence of lipoic acid (concentrations ranging from 0.5 μ M to 500 μ M) for 8-15 hours. Each lens was removed from medium, weighed, and photographed on a micrometer scale. A coverslip of known
15 weight (0.17899 ± 0.00200 g) was placed on the lens, and the lens was photographed again on the micrometer scale. The diameter of each lens with and without the coverslip was determined from the photographs. The change in lens diameter produced by the force (coverslip) was computed $\Delta D = (D_{\text{withcoverslip}} - D_{\text{withoutcoverslip}})$. The results (Fig. 4, ‡) indicate that lipoic acid at concentrations ≥ 9.6 μ M caused a statistically significant increase in ΔD , p
20 < 0.0001 .

[0047] *Decrease in disulfide bonds:* Lipoic acid at concentrations ≥ 9.6 μ M caused a statistically significant decrease in protein disulfides in the mouse lenses where there was a significant increase in ΔD (Fig. 4). Mouse lenses were homogenized in a denaturing buffer containing a fluorescent alkylating agent to modify the free SH groups. After removing the
25 alkylating agent homogenates were reduced and alkylated with a different fluorescent alkylating agent. Absorption spectra of the modified proteins were used to calculate free protein SH and protein SS groups. The results are shown in Fig. 5.

[0048] Example 3: Preclinical and clinical studies

[0049] An exemplary clinical protocol may include patient selection criteria of age 45-55
30 years with some loss of clinical accommodative amplitude.

[0050] A test compound and/or placebo control may be administered in a controlled dark sterile environment with 1-photon visible light LED (computer controlled tilt mirror) system.

[0051] For acute treatment, the clinician could 1) apply a topical mydriatic agent, 2) wait for pupillary dilatation (about 5 minutes), 3) introduce a test compound and/or placebo control with an appropriate delivery device, 4) wait 30 minutes, and 5) apply topical agent (e.g., cholecystokinin and vasopressin) to retract iris sphincter muscle to aid release of zonular tension during lens cytosol protein remodeling.

[0052] Immediately following the procedure, the clinician may allow a time period for ocular drug clearance (e.g., about 30-60 minutes) and then allow patient to go home with laser glasses having a cutoff filter of about > 550 nm.

[0053] For post-operative follow-up in about 1 day to 1 week, the clinician may evaluate the treatment modality for a desired visual endpoint, e.g., accommodative amplitude or elasticity.

[0054] The procedure can be repeated to gain further efficacy (e.g., to obtain 2 D in patients older than 55 years) and/or to restore near vision (depending on the duration of action).

[0055] A similar protocol could be adapted for preclinical testing animal in vivo lens models.

[0056] The examples given above are merely illustrative and are not meant to be an exhaustive list of all possible embodiments, applications, or modifications of the invention. Thus, various modifications and variations of the described methods and systems of the invention will be apparent to those skilled in the art without departing from the scope of the invention. Although the invention has been described in connection with specific embodiments, it should be understood that the invention as claimed should not be unduly limited to such specific embodiments. Indeed, various modifications of the described modes of carrying out the invention which are obvious to those skilled in the chemical arts or in the relevant fields are intended to be within the scope of the appended claims.

WHAT IS CLAIMED IS:

1. A pharmaceutical composition for ocular use comprising a compound that is:
 - 5-(1,2-dithiolan-3-yl)pentanoic acid;
 - 6,8-dimercaptooctanoic acid;
 - dihydrolipoate;
 - 5-(1,2-thiaselenolan-5-yl)pentanoic acid;
 - 5-(1,2-thiaselenolan-3-yl)pentanoic acid;or a salt or ester thereof, in an amount of 10 μM to 250 μM and at least one pharmaceutically acceptable excipient.
2. The pharmaceutical composition of claim 1, wherein the compound is present in an amount of 10 μM to 100 μM .
3. The pharmaceutical composition of claim 1, wherein the compound is 5-(1,2-dithiolan-3-yl)pentanoic acid or a salt or ester thereof.
4. The pharmaceutical composition of claim 1, wherein the compound is 6,8-dimercaptooctanoic acid, dihydrolipoate, or a salt or ester thereof.
5. The pharmaceutical composition of claim 1, wherein the compound is 5-(1,2-thiaselenolan-5-yl)pentanoic acid; 5-(1,2-thiaselenolan-3-yl)pentanoic acid; or a salt or ester thereof.
6. The pharmaceutical composition of claim 1, wherein the compound is the R enantiomer.
7. The pharmaceutical composition of claim 1, wherein the at least one pharmaceutically acceptable excipient comprises an emulsifier and a buffered carrier.

8. Use of a pharmaceutical composition for preventing or treating oxidative damage-related disorders in ocular cells in a subject, the pharmaceutical composition comprising a compound that is:

5-(1,2-dithiolan-3-yl)pentanoic acid;

6,8-dimercaptooctanoic acid;

dihydrolipoate;

5-(1,2-thiaselenolan-5-yl)pentanoic acid;

5-(1,2-thiaselenolan-3-yl)pentanoic acid;

or a salt or ester thereof, in an amount of 10 μ M to 250 μ M and at least one pharmaceutically acceptable carrier, wherein the pharmaceutical composition is administrable to the subject,

and

wherein the use increases accommodative amplitude to, or maintains an accommodative amplitude of, at least 2% greater than the accommodative amplitude expected in an untreated lens of about the same age as measured in diopters, or

the use increases accommodative amplitude by at least 0.25 diopters, or

the use increases lens elasticity to, or maintains a lens elasticity of, at least 2% greater than the elasticity expected in an untreated lens of about the same age as measured by E, or

the use decreases lens opacity to, or maintains lens opacity at, at least 2% less than the opacity expected in an untreated lens of about the same age.

9. Use of a pharmaceutical composition for the manufacture of a medicament for preventing or treating oxidative damage-related disorders in ocular cells in a subject, the pharmaceutical composition comprising a compound that is:

5-(1,2-dithiolan-3-yl)pentanoic acid;

6,8-dimercaptooctanoic acid;

dihydrolipoate;

5-(1,2-thiaselenolan-5-yl)pentanoic acid;

5-(1,2-thiaselenolan-3-yl)pentanoic acid;

or a salt or ester thereof, in an amount of 10 μM to 250 μM and at least one pharmaceutically acceptable carrier, wherein the pharmaceutical composition is administrable to the subject,

and

wherein the use increases accommodative amplitude to, or maintains an accommodative amplitude of, at least 2% greater than the accommodative amplitude expected in an untreated lens of about the same age as measured in diopters, or

the use increases accommodative amplitude by at least 0.25 diopters, or

the use increases lens elasticity to, or maintains a lens elasticity of, at least 2% greater than the elasticity expected in an untreated lens of about the same age as measured by E, or

the use decreases lens opacity to, or maintains lens opacity at, at least 2% less than the opacity expected in an untreated lens of about the same age.

10. The use of claim 8 or 9, wherein the compound is administrable simultaneously or consecutively with a chemical energy source, and wherein the chemical energy source is glucose or NADPH.

11. The use of claim 10, wherein the compound is administrable simultaneously with the chemical energy source.

12. The use of claim 8 or 9, wherein the cells are in vivo.

13. The use of claim 12, wherein the pharmaceutical composition is administrable via a topical ocular, subtenons, subconjunctival, intracameral, intravitreal, or iontophoresis route.

14. The use of claim 8 or 9, wherein the ocular cells are lens cells, and wherein the use increases accommodative amplitude to, or maintains an accommodative amplitude of, at least 2% greater than the accommodative amplitude expected in an untreated lens of about the same age as measured in diopters.

15. Use of a pharmaceutical composition for decreasing inelasticity of a human lens in a human, the pharmaceutical composition comprising 10 μM to 500 μM of lipoic acid or derivative thereof and at least one pharmaceutically acceptable carrier, wherein the pharmaceutical composition is administrable to the human.

16. Use of a pharmaceutical composition for the manufacture of a medicament for decreasing inelasticity of a human lens, the pharmaceutical composition comprising 10 μM to 500 μM of lipoic acid or derivative thereof and at least one pharmaceutically acceptable carrier, wherein the medicament is administrable to the human.

17. Use of 10 μM to 500 μM of lipoic acid or derivative thereof for treating or preventing presbyopia in a subject, wherein the lipoic acid or derivative thereof is administrable to the subject.

18. Use of 10 μM to 500 μM of lipoic acid or derivative thereof for the manufacture of a medicament for treating or preventing presbyopia in a subject, wherein the medicament is administrable to the subject.

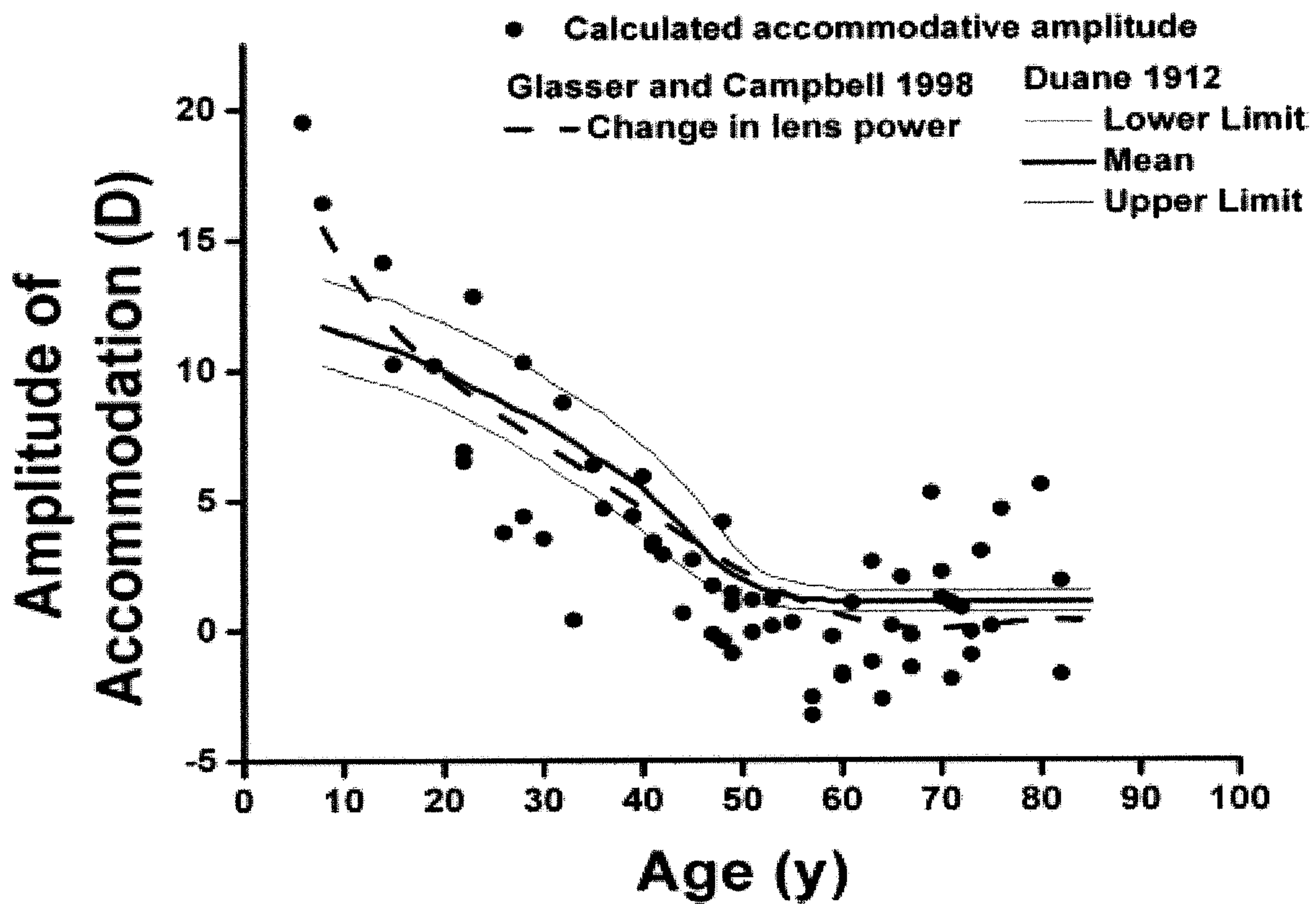


Figure 1

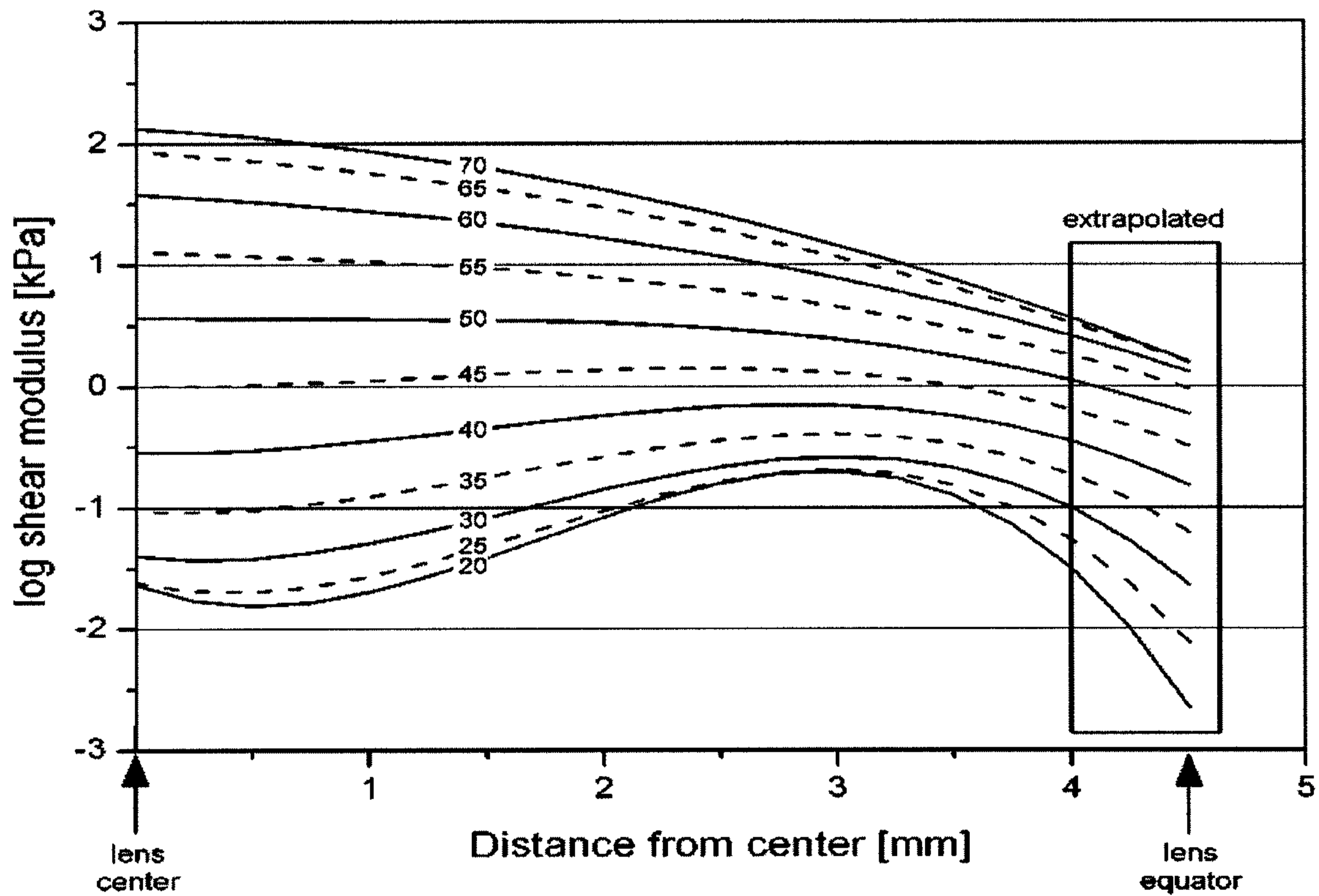


Figure 2

3 / 5

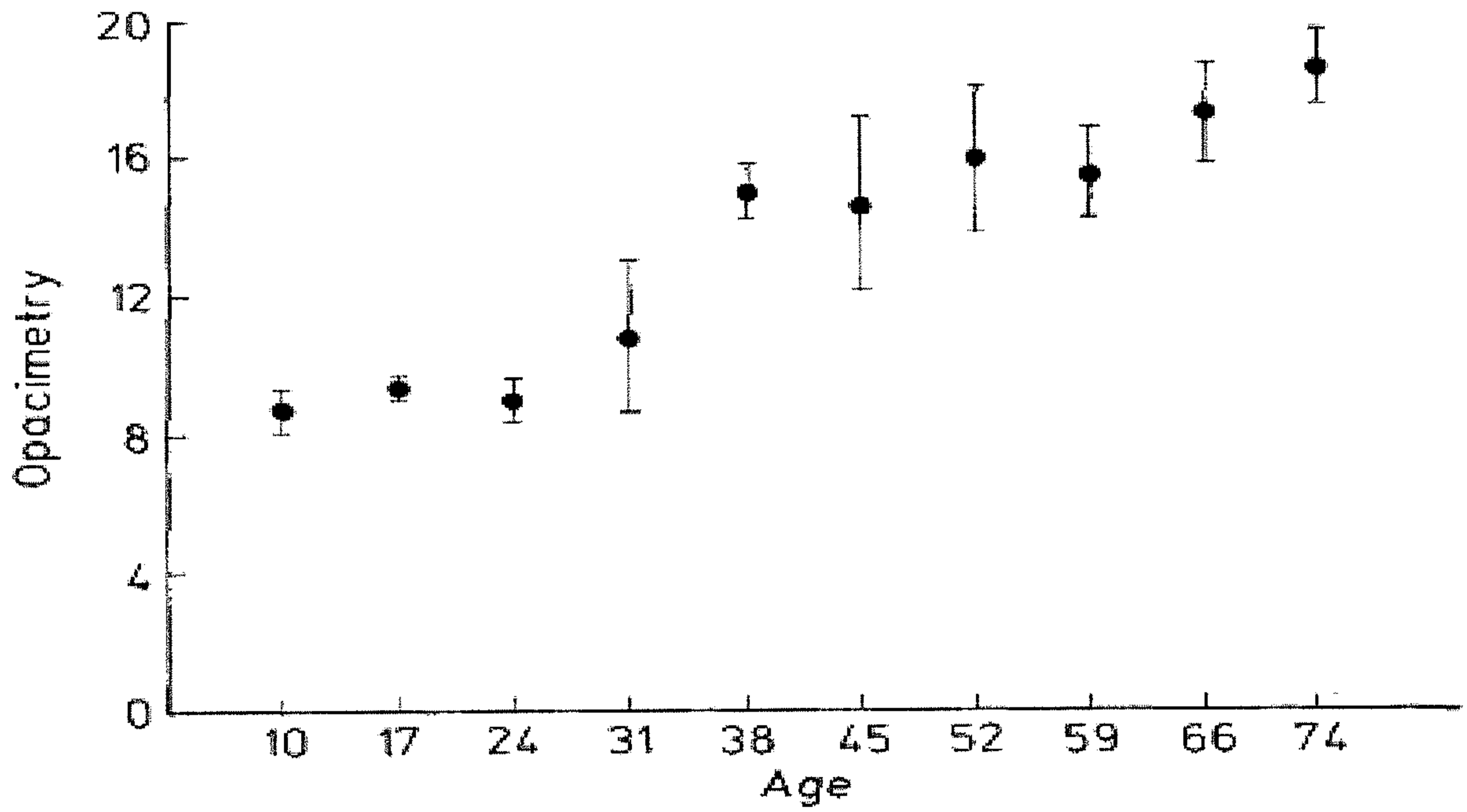


Figure 3

4 / 5

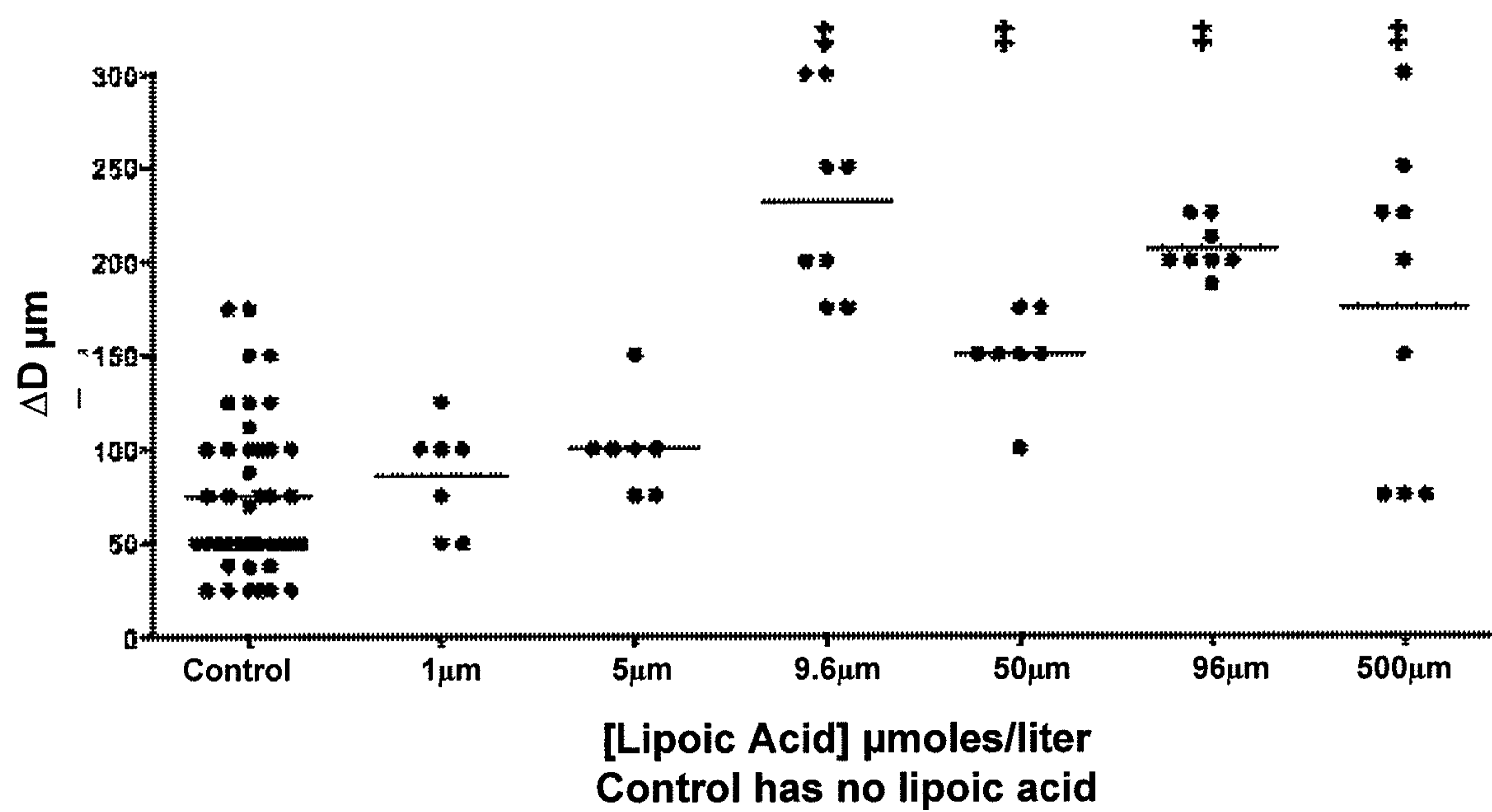


Figure 4

5 / 5

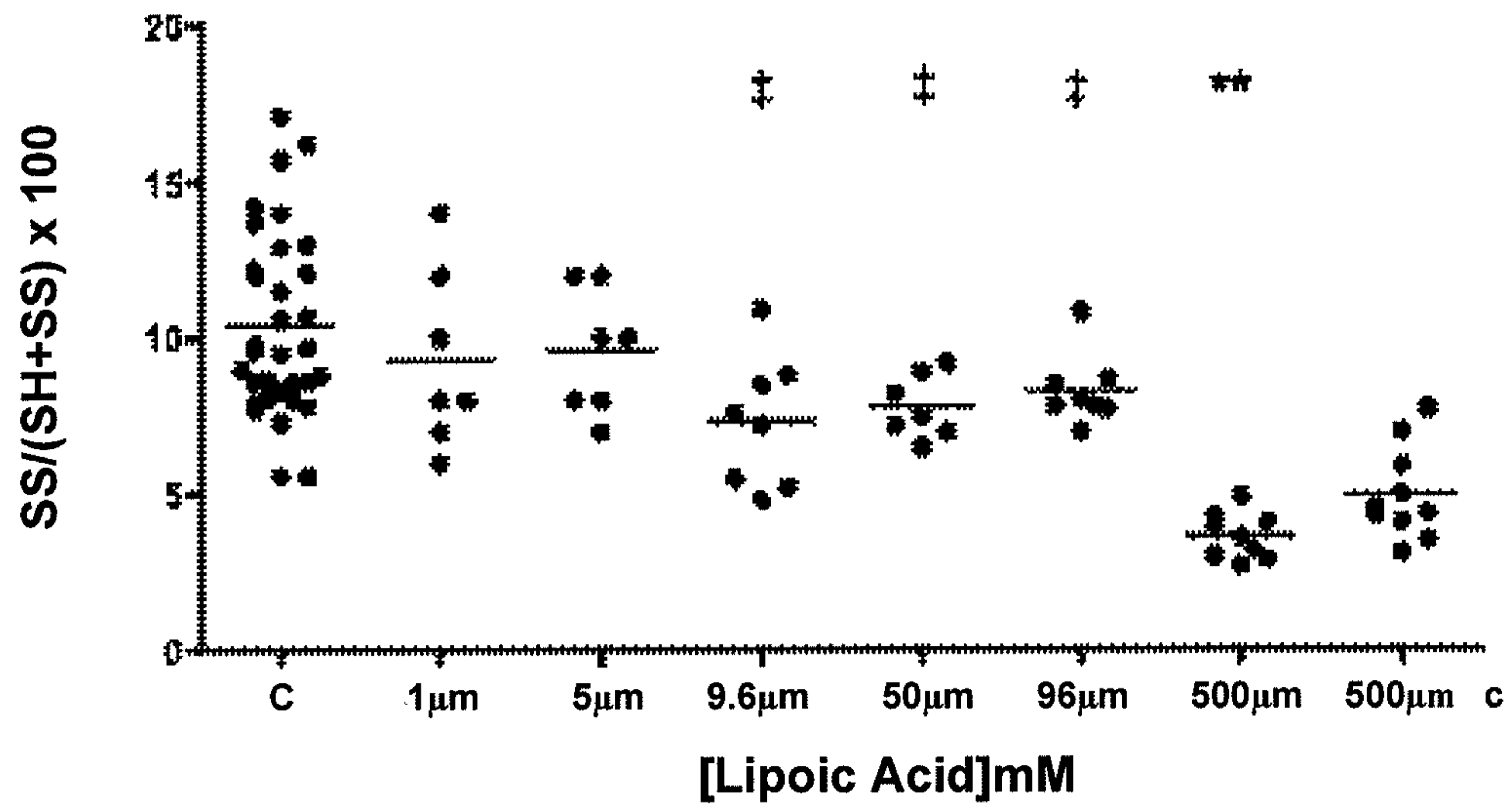


Figure 5