The Effects of a Dietary Supplement Containing Astaxanthin on the Accommodation Function of the Eye in Middle-aged and Older People

Masayoshi Kajita[1)], Hiroki Tsukahara[2)], Mio Kato[1)]

Introduction

Presbyopia is a symptom of the decreasing accommodation ability of the eye that makes it difficult to focus on nearby objects with increasing age, gradually advancing from the 40's. In people with presbyopia, due to the decreased elasticity of the lens, even though the ciliary muscle contracts, the lens does not swell, with no increase in refractive power. Functional deterioration of the ciliary muscles with aging is one of the causes for presbyopia, but it is considered that functional deterioration of the constrictor pupillae muscle and dilator pupillae muscle is also involved. If left untreated, symptoms of asthenopia including shoulder stiffness, ocular pain and headache will occur and the quality of life may be significantly impaired. The first-line choice for treatment is the implementation of measures to improve the acuity of nearby vision by means of reading glasses, etc.

Astaxanthin ("AX"), which is one of the carotenoids, has an extremely strong quenching ability against singlet oxygen and inhibiting activity against lipid peroxidation, which are reported to be several hundred times the activity of α-tocopherol.[1-3)] Since AX is contained in aquatic animals such as salmon, shrimps and crabs, it can be said to be a functional food ingredient that has been ingested by humans for a long time.

In recent years, a considerable number of reports has described that taking AX can improve subjective symptoms such as eye strain in visual display terminal (VDT) operators and the accommodation ability.[4-6)] This time, we investigated the effects of AX supplementation on the accommodation function of the eye in middle-aged and older people in whom presbyopia had begun.

The near reflex was measured by TriIRIS C9000 before and after AX supplementation, and the pupillary constriction ratio was calculated for assessment.

I. Subjects and Study Design

1. Subjects

Twenty-two people who had given written informed consent for participation in this study and met all inclusion criteria, but did not violate any exclusion criteria, described below, were selected to be enrolled in this study.

1) Inclusion criteria

(1) Healthy adult male volunteers aged 45 or over, but under 65;

(2) Constant eye strain in daily life;

(3) No eye diseases excluding ametropia;

[1] Kajita Eye Clinic
[2] Life Science Division, Fuji Chemical Industry Co., Ltd.

(4) Able to keep eyes open without blinking for at least 30 seconds;

(5) Able to follow the compliance rules described in the study protocol, and to undergo tests and examinations on scheduled days.

2) Exclusion criteria

(1) Presence of a concomitant drug allergy or such history;

(2) Regularly intake of any drugs or health food products effective for asthenopia (e.g., vitamins, supplementary drinks containing taurine);

(3) Considered unsuited for the study at the discretion of the investigator based on other reasons.

3) Consent for participation in the study

The investigators explained the following contents to subjects prior to initiating the study to obtain written informed consent for participation in this study on a voluntary basis.

(1) The purpose, methods and duration of the study;

(2) That the confidentiality of information on subjects will be protected;

(3) The compensation that subjects can receive if health problems occur during the study;

(4) The right to refuse to participate in the study, or to withdraw consent to participate at any time without any disadvantages;

(5) The address to be contacted when disorders considered related to health conditions may occur during the study period.

(6) Compliance rules that subjects should follow.

2. Study Design

1) Investigational food product

As the investigational food product, a dietary supplement containing 6 mg of AX derived from Haematococcus algae in each soft gel capsule was used. The investigational food product for 4 weeks, packed in an aluminum package, was handed to subjects.

2) Amount and duration of supplementation

Subjects were instructed to take one soft capsule mentioned above (containing 6 mg of AX as free form) with water, without chewing it, once daily after the evening meal.

The duration of supplementation was set at 4 weeks. The amount and duration of supplementation were established in reference to reports of previously conducted studies that suggested effectiveness.[4, 5)]

3) Test and time point

(1) Uncorrected visual acuity was measured before and at 4 weeks after supplementation of the investigational food product, and was converted into logMAR units.

(2) The near response was measured by TriIRIS C9000 before and at 4 weeks after supplementation of the investigational food product.

a. The vision of subjects was corrected in advance with glasses that would give them clear vision at a distance of 50 cm (shortest distance of distinct vision).

b. The visual acuity chart was gradually moved from the 50 cm distance to determine the near point.

c. The movement amplitude of the near point + 1 Diopter was set as the accommodation stimulus.

d. The visual acuity chart was moved back and forth three times over the distance from the 50-cm point to the "near point + 1 Diopter." During this period, the constricted pupil diameter and the convergence were measured and recorded continuously as the transverse diameter of the central portion and the locus of the central portion, respectively.

e. The pupillary constriction ratio was defined as [initial pupil diameter (mm) – constricted pupil diameter at the third measurement (mm)]/ initial pupil diameter (mm). The pupillary constriction ratio was compared before and after ingestion of the investigational food product to assess the effects of the investigational food product on the accommodation function.

4) Health interview conducted by physician

A health interview was conducted by the physician before and at 4 weeks after supplementation of the investigational food product to examine the health condition and subjective symptoms during the study.

5) Questionnaire on subjective symptoms for completion by subjects

The following symptoms were examined at 4 weeks after supplementation of the investigational food product. Symptoms that had been present before supplementation of the investigational food product were rated on a scale of one to five (1: significantly improved; 2: improved; 3: slightly improved; 4: unchanged; 5: worsened) to be compared with the scores before supplementation of the investigational food product.

1: difficulty to see nearby objects; 2: difficulty to see far objects; 3: eye strain; 4: ocular pain; 5: blurred vision; 6: eye redness; 7: flashing vision; 8: lacrimation; 9: shoulder and low back stiffness; 10: dull headache

6) Analysis methods

The paired t-test was employed and a significance level of less than 5% was considered statistically significant.

II. Study Results

1. Subject Background

The backgrounds of subjects are shown in Table 1. The 22 subjects enrolled in this study were all male, aged between 46 and 65 years with a mean age of 53.9 ± 5.1 years. Nineteen out of 22 subjects were using glasses routinely and no subjects were using contact lenses.

Table 1 Subject Background

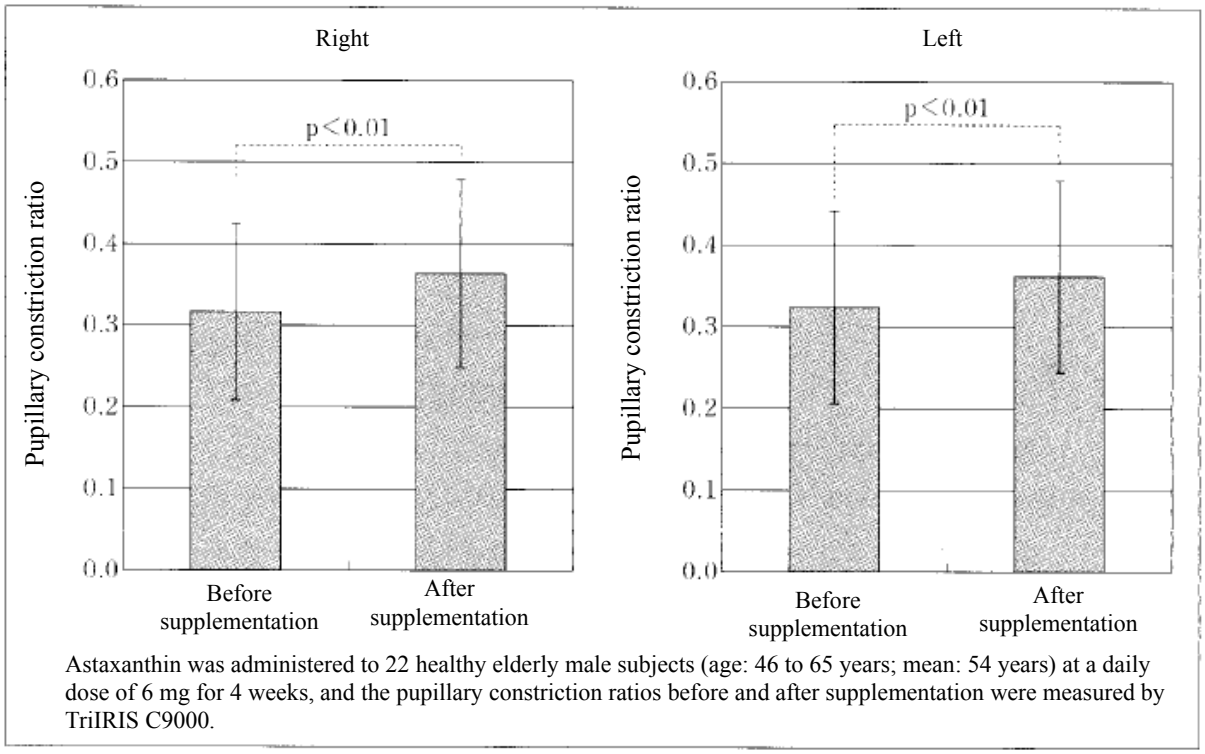
Age (years)	53.9±5.1 (46-65)
Height (cm)	171.8±5.1 (161-180)
Weight (kg)	66.7±6.3 (52-75)
Use of glasses (number of subjects)	Yes: 19
	No: 3
Use of contact lens (number of subjects)	Yes: 0
	No: 22

Total number of subjects: 22 (male); Each value: mean ± S.D.

Table 2 Uncorrected Visual Acuity

	Right		Left	
Uncorrected visual acuity (logMAR units)	Before ingestion	After ingestion	Before ingestion	After ingestion
	0.85±0.53	0.84±0.54 N.S.	0.83±0.55	0.76±0.52 N.S.

Total number of subjects: 22 (male); Each value: mean ± S.D.; N.S.: not significant



Astaxanthin was administered to 22 healthy elderly male subjects (age: 46 to 65 years; mean: 54 years) at a daily dose of 6 mg for 4 weeks, and the pupillary constriction ratios before and after supplementation were measured by TriIRIS C9000.

Figure 1 Pupillary Constriction Ratio Before and AfterSupplementation of the Investigational Food Product

Table 3 Results of a Questionnaire Survey on Subjective Symptoms in Subjects

Symptoms	Number of subjects who answered "slightly improved" or better[a] / Number of subjects who had had the relevant symptom before ingestion	Percentage of subjects who answered "slightly improved" or better[a]
1. Difficulty to see nearby objects	13/20	65.0%
2. Difficulty to see far objects	7/15	46.7%
3. Eye strain	17/22	77.2%
4. Ocular pain	6/13	46.2%
5. Blurred vision	11/18	61.1%
6. Eye redness	3/16	18.8%
7. Flashing vision	5/14	35.7%
8. Lacrimation	2/13	15.4%
9. Shoulder and low back stiffness	12/19	63.2%
10. Dull headache	4/12	33.3%

a: Subjects who answered "significantly improved," "improved," or "slightly improved" in a questionnaire survey conducted after ingestion, by which each symptom was assessed on a 5-point scale ("significantly improved," "improved," "slightly improved," "unchanged," and "worsened") in subjects who had had the relevant symptom before ingestion.

2. Uncorrected Visual Acuity

Uncorrected visual acuity (logMAR units) before and after supplementation of the investigational food product is shown in Table 2. The right visual acuity before and after supplementation was 0.85 ± 0.53 and 0.84 ± 0.54, respectively, and the left visual acuity was 0.83 ± 0.55 and 0.76 ± 0.52, respectively, showing no significant changes after supplementation of the investigational food product both in the right and left eyes.

3. Pupillary Constriction Ratio

Prior to measurement, subjects were instructed to strictly observe the precautions such as "Do not move your jaw and forehead during measurement, and avoid blinking as much as possible." To enable subjects to concentrate on the measurement, we aroused subjects by calling them around the near point to raise their concentration level.

The pupillary constriction ratio before and after supplementation of the investigational food product is shown in Figure 1. For the right eye, the pupillary constriction ratio before and after supplementation was 0.32 ± 0.11 and 0.36 ± 0.12, respectively, showing a significant increase after supplementation ($p < 0.01$). For the left eye, the pupillary constriction ratio before and after supplementation was 0.32 ± 0.12 and 0.36 ± 0.12, respectively, also showing a significant increase after supplementation ($p < 0.05$). The number of subjects in whom the pupillary constriction ratio increased in the right eye after supplementation was 16 out of 22, and that in the left eye was 14, and that in both eyes was 12.

4. Questionnaire on Subjective Symptoms of Subjects

The results of the questionnaire on subjective symptoms are shown in Table 3. Symptoms about how many subjects had complained before supplementation of the investigational food product were as follows: "difficulty to see nearby objects" (20 subjects); "eye strain" (22); "blurred vision" (18); and, "shoulder and low back stiffness" (19). The percentage of subjects who answered "slightly improved" or better for these symptoms after supplementation were 65.0%, 77.2%, 61.1% and 63.2%, respectively.

III. Discussion

Astaxanthin (AX), one of the carotenoids, has extremely strong quenching ability against singlet oxygen and inhibiting activity against lipid peroxidation.[1-3] It possesses various pharmacological activities including anti-inflammatory activity,[7, 8] antiulcer activity,[9] antidiabetic activity,[10] and muscle fatigue relieving activity,[11] and not a few reports have been published on clinical trials conducted in subjects complaining of eye strain.[4-6, 12-14]

In a previous report,[4] the following results were obtained: In a randomized double-blind placebo controlled study in which AX (daily dose of 6 mg) or placebo was administered to VDT operators with chronic complaint of eye strain for 4 weeks to investigate the effects of AX on eye strain, AX showed significant improvement in the accommodation ability, which is considered an objective index of the degree of eye strain (measured by a constant point refraction near point ruler, "D'ACOMO"), as well as improvement in symptoms accompanied by asthenopia such as "shoulder and low back stiffness" and "blurred vision." In another clinical study[6] conducted in healthy volunteers in which the effects of rest after VDT operation on recovery of accommodation function were measured by an analyzer of High Frequency Component in Accommodative micro-fluctuation ("AA-1," NIDEK Co., Ltd.), it was suggested that AX would show effects on accommodation function and promote the recovery process of accommodative fatigue to alleviate fatigue immediately. Many of these studies were conducted in subjects aged from their late 20's to their late 30's, in whom the accommodation ability for focusing the eye is relatively preserved. In our present study, middle-aged and older people were targeted and the effects of AX on their accommodation function and subjective symptoms were investigated. The pupillary constriction ratio was calculated using TriIRIS C9000 to assess the accommodation function, and the effects on subjective symptoms were examined by a questionnaire survey of subjects.

Presbyopia is a phenomenon that the accommodation ability to focus the eye declines with aging, making it difficult to focus on nearby objects, and is said to progress gradually from the 40's. Accompanying symptoms include difficulty to see nearby objects, eye strain, shoulder stiffness, dull eye, dull headache and headache. This study was conducted in 22 subjects aged between 46 and 65 (mean: 54 years) with the following complaints: "eye

strain" (all 22 subjects); "difficulty to see nearby objects" (20); "shoulder and low back stiffness" (19); "blurred vision" (18). Based on this, we considered that middle-aged and older people with typical presbyopia were enrolled in this study.

Concerning uncorrected visual acuity, as reported in previous clinical studies that AX had no effects on it, no significant changes were observed in our study, either.

The accommodation function was assessed by calculating the pupillary constriction ratio using TriIRIS C9000. This device is capable of simply measuring the change in convergence response and miotic response induced by accommodation following near vision, under physiological conditions with both eyes open.[15] In many studies this device has been used for various tests including the presbyopia test (test for accommodation function), the test of abnormal accommodation due to asthenopia induced by VDT operations, etc., and the test for accommodation function before and after eye surgery.[16-18] Since significant increases were observed in the pupillary constriction ratios in both the right and left eyes, AX is considered to have positively activated the functions of the constrictor pupillae muscle and dilator pupillae muscle, which are responsible for miosis and mydriasis, respectively. It is estimated that AX will activate the ciliary muscle by improving the blood flow,[19] but it is also considered that AX may also improve the blood flow in the constrictor pupillae muscle and the dilator pupillae muscle. The ciliary muscle is composed of a circular muscle and a longitudinal muscle, which are considered to move in coordination with the constrictor pupillae muscle and the dilator pupillae muscle, since these muscles are innervated by the same motoneuron. It is also considered that if the function of the ciliary muscle is activated, the ratio of the pupillary constriction due to the pupil response to nearby vision may be improved.

Concerning subjective symptoms, those for which many subjects answered, "slightly improved" or better were as follows: "eye strain," "difficulty to see near objects," "blurred vision," and "shoulder and low back stiffness." In a double-blind study in adult subjects with eye strain, it was already shown that "blurred vision" and "shoulder and low back stiffness" were significantly improved after taking AX.[4] It is suggested that improvement in the subjective symptoms might have been achieved by deep depth of focus and ease of focusing that resulted from the active movement of the pupils (increase in pupillary constriction ratio) caused by the action of the constrictor pupillae muscle and the dilator pupillae muscle activated by AX.

The basic measure for presbyopia is to wear glasses. However, since improvement in both the accommodation function and subjective symptoms was observed in this study conducted in middle-aged and older people with presbyopia, it was suggested that the supplementation of AX may slow down the progression of presbyopia and myopia associated with focusing on nearby objects and improve asthenopia in middle-aged and older people with advanced presbyopia as well as in younger adults.

IV. Conclusion

The effects of a dietary supplement containing astaxanthin on the accommodation function and subjective symptoms of the eyes were investigated in 22 middle-aged and older people (mean age: 53.9 years) with complaints of eye strain. Astaxanthin was administered to subjects at a daily dose of 6 mg for 4 weeks, and the pupillary constriction ratio before and after AX supplementation was measured by TriIRIS C9000. The change in subjective symptoms after supplementation was examined by a questionnaire. The results showed a significant increase in pupillary constriction ratio after supplementation of AX, therefore suggesting that astaxanthin may also improve the accommodation function of the eye and some subjective symptoms related to presbyopia in middle-aged and older people with complaints of eye strain.

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アスタキサンチン含有ソフトカプセルの中高齢者の眼の調節機能に及ぼす影響

梶田雅義[1)]
塚原寛樹[2)]
加藤未央[1)]

はじめに

老視は，加齢に伴い調節力が低下し近見作業が困難となる症状で，40歳代から徐々に進行する。水晶体の弾性が低下しているので毛様体筋が収縮しても水晶体は膨らまず，屈折力が増加しない状態である。加齢に伴う毛様体筋機能低下も一因であるが，瞳孔括約筋，瞳孔散大筋の機能低下も伴うと考えられる。放置すると肩こり，眼の痛み，頭痛など眼精疲労の症状が発現し，QOLを大きく損なうが，老眼鏡等を用いた近方視対策を行うことが治療の第一選択である。

アスタキサンチン（以下AX）は，非常に強い一重項酸素消去能と脂質過酸化抑制作用を有するカロテノイドの一種であり，その活性はα-トコフェロールの数百倍と報告されている[1~3]。サケ，エビ，カニなどの魚類にも多く含まれており，ヒトでの食経験が長い機能性食品である。

近年AXを摂取することにより，Visual Display Terminal（VDT）作業者の疲れ目などの自覚症状と調節力が改善することが数多く報告されている[4~6]。今回，我々は老視が始まった中高齢者を対象に，眼の調節機能に及ぼすAX摂取の影響を検討した。

AX摂取前後でトライイリスC9000を用いて近見反射を測定し，縮瞳率を計算して評価した。

1）梶田眼科
2）富士化学工業株式会社ライフサイエンス事業部

Ⅰ．被験者および試験方法

1．被験者

本試験の参加に文書で同意し，以下の選択基準を満たし除外基準に抵触しない者22名を選択し，本試験の被験者とした。

1）選択基準
(1) 年齢45歳以上65歳未満の健常成人男子
(2) 日常生活において恒常的に眼の疲れを感じる者
(3) 屈折異常以外に眼疾患を有さない者
(4) 30秒以上まばたきをせず眼を開けていることができる者
(5) 試験計画書に定められた遵守事項を守り，定められた日に検査，診察を受けることができる者

2）除外基準
(1) 薬剤アレルギーの合併あるいは既往のある者
(2) 常時医薬品や眼精疲労に効果のある健康食品（ビタミン剤やタウリン配合ドリンク剤）などを服用している者
(3) その他試験責任医師が不適当と認める者

3）試験参加への同意

試験責任医師は試験開始前に以下に定める事項を被験者に説明し，試験への参加について自由意志による文書同意を得た。

(1) 試験の目的および方法，実施期間
(2) 被験者の秘密は保全されること
(3) 試験中に健康被害が発生した場合に被験者が受けることができる補償

(4) 試験参加を随時拒否または撤回することができ，また，撤回することにより不利益な扱いを受けないこと
(5) 試験中に健康に関連すると思われる障害が生じた場合の連絡先
(6) 被験者が守るべき事項

2. 試験方法

1) 試験食品

試験食品はヘマトコッカス藻由来のAXを6 mg含有するソフトカプセルを用いた。4週間分の試験食品をアルミ袋に入れ被験者に手渡した。

2) 摂取量・摂取期間

上記ソフトカプセル1粒（AXフリー体換算で6 mgを含有）を毎夕食後噛まずに水などで摂取させた。

摂取期間は4週間とした。摂取量と摂取期間は，既に実施され有効性が示唆されている報告[15]を参考に設定した。

3) 検査とその時期

(1) 試験食品摂取前と摂取4週後に裸眼視力を測定し，logMAR値に換算した。
(2) 試験食品摂取前と摂取4週後にトライイリスC9000を用いて近見反応を測定した。
① 被験者に予め50 cmの距離が楽に明視できる眼鏡で矯正を行う。
② 指標を50 cmの距離からゆっくり移動させ近点を決定する。
③ 近点＋1 Diopterの移動幅を調節刺激に設定する。
④ 50 cmから近点＋1 Diopterの距離まで指標が3回往復し，その間に縮瞳と輻輳が測定される。瞳孔径は中心部横径，輻輳は中心部軌跡として連続記録される。
⑤ ［初期瞳孔径（mm）－3回目縮瞳径（mm）］÷初期瞳孔径（mm）を縮瞳率とし，試験食品摂取前後の縮瞳率を比較して試験食品の調節機能に及ぼす影響を評価した。

4) 医師による問診

試験食品摂取前と摂取後4週後に医師による問診を行い，試験中の健康状態，自覚症状等について調査した。

5) 被験者による自覚症状に関するアンケート調査

試験食品摂取4週後に以下の項目について調査した。試験食品摂取前に症状があった項目につき，試験食品摂取前と比較して，① 非常に良くなった，② 良くなった，③ やや良くなった，④ 変わらない，⑤ 悪くなったの5段階で評価した。

1. 近いところが見えにくい，2. 遠いところが見えにくい，3. 眼が疲れる，4. 眼が痛い，5. 眼がかすむ，6. 眼が赤くなる，7. 物がちらついて見える，8. 涙がでる，9. 肩・腰がこる，10. 頭が重い

6) 解析方法

対応のあるt検定で行い，有意水準は危険率5%未満を基準とした。

II. 試験結果

1. 被験者の背景

被験者の背景を表1に示した。被験者22名は全員男性で，平均年齢53.9 ± 5.1歳で46 ～ 65歳の者が試験に組み入れられた。日常的に眼鏡を使用している者は22名中19名で，コンタクトレンズ使用者はいなかった。

表1 被験者背景

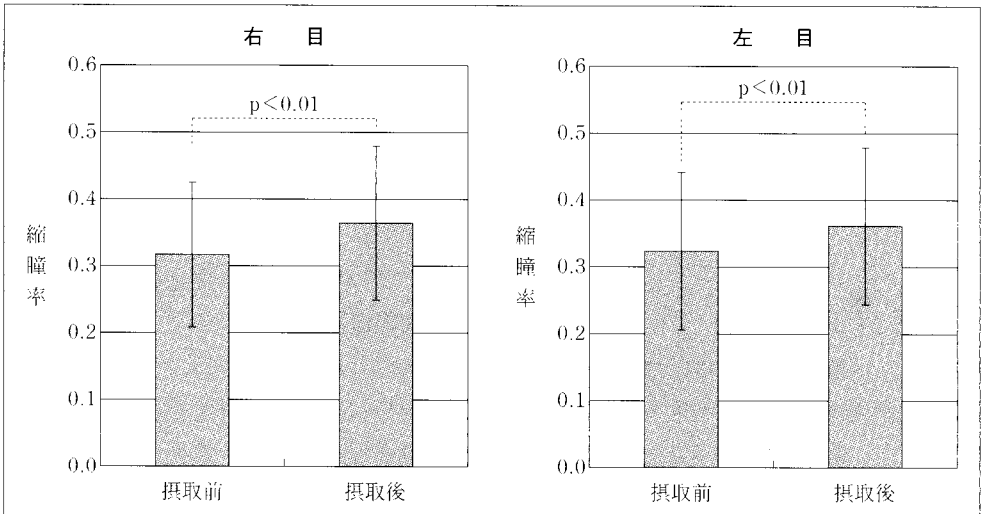
年齢（歳）		53.9 ± 5.1（46 ～ 65）
身長（cm）		171.8 ± 5.1（161 ～ 180）
体重（kg）		66.7 ± 6.3（52 ～ 75）
眼鏡（名）	あり	19
	なし	3
コンタクトレンズ（名）	あり	0
	なし	22

被験者数：22名（男性） 数値は平均±標準偏差

表2 裸眼視力

	右目		左目	
	摂取前	摂取後	摂取前	摂取後
裸眼視力（logMAR値）	0.85 ± 0.53	0.84 ± 0.54 N. S.	0.83 ± 0.55	0.76 ± 0.52 N. S.

被験者数：22名（男性） 数値は平均±標準偏差 N. S.：not significant



健常男性高齢被験者（年齢：46～65歳，平均54歳）22名にアスタキサンチン1日量6 mgを4週間摂取させ，摂取前後にトライイリスC9000を用いて縮瞳率を測定した。

図1　試験食品摂取後の縮瞳率

表3　被験者の自覚症状に関するアンケート結果

症　状	「やや良くなった」以上[a]の例数／摂取前に症状があった例数	「やや良くなった」以上[a]の割合（%）
1. 近いところが見えにくい	13/20	65.0%
2. 遠いところが見えにくい	7/15	46.7%
3. 眼が疲れる	17/22	77.2%
4. 眼が痛い	6/13	46.2%
5. 眼がかすむ	11/18	61.1%
6. 眼が赤くなる	3/16	18.8%
7. 物がちらついて見える	5/14	35.7%
8. 涙が出る	2/13	15.4%
9. 肩・腰がこる	12/19	63.2%
10. 頭が重い	4/12	33.3%

[a] 摂取前に各症状を有していた被験者において，摂取後にアンケートにより「非常に良くなった」，「良くなった」，「やや良くなった」，「変わらない」，「悪くなった」の5段階で評価を行い，「非常に良くなった」，「良くなった」，「やや良くなった」と答えた被験者。

2. 裸眼視力

表2に試験食品摂取前後の裸眼視力（logMAR値）を示した。右目は摂取前0.85 ± 0.53，摂取後0.84 ± 0.54，左目は摂取前0.83 ± 0.55，摂取後0.76 ± 0.52であり，左右目とも試験食品摂取による有意な視力の変化はみられなかった。

3. 縮瞳率

検査に先立って，「検査中はあごと額を動かさないように，なるべく瞬きを我慢するように」などの注意事項を被験者に徹底させた。また，被験者が検査に集中できるように近点付近で声掛けを行い，被験者の集中度を高めるようにした。

図1に試験食品摂取後の縮瞳率を示した。右目については，摂取前縮瞳率は0.32 ± 0.11，摂取後は0.36 ± 0.12であり，摂取後に有意な増加がみられた（$p < 0.01$）。一方，左目については，摂取前縮瞳率は0.32 ± 0.12，摂取後は0.36 ± 0.12であり，摂取後に有意な増加が認められた（$p < 0.05$）。摂取後に縮瞳率が増加した被験者は，右目で22名中16名，左目で14名であり，両眼ともに増加した被験者は22名中12名であった。

4. 被験者の自覚症状に関するアンケート

表3に自覚症状に関するアンケート結果を示した。試験食品摂取前に被験者の多くが訴えた症状は，

「近いところが見えにくい」（20名），「眼が疲れる」（22名），「眼がかすむ」（18名）および「肩・腰がこる」（19名）があった。摂取後これらの症状に関して「やや良くなった」以上と答えた被験者の割合は，それぞれ65.0%，77.2%，61.1%および63.2%であった。

Ⅲ. 考　　察

アスタキサンチン（AX）は，非常に強い一重項酸素消去能と過酸化脂質抑制作用を有するカロテノイドの一種である[1~3]。薬理学的作用として抗炎症作用[7,8]，抗潰瘍作用[9]，抗糖尿病作用[10]，抗筋肉疲労作用[11]など多彩な作用を有するが，臨床試験については，疲れ眼を訴えるヒトを対象にした試験が多く報告されている[4~6,12~14]。

日常的に疲れ眼を訴えるVDT作業者にAX（1日量6 mg）またはプラセボを4週間摂取させ，二重盲検群間比較法でAXの疲れ眼に対する影響を検討した試験において，AXは疲れ眼の客観的指標と考えられる調節力（定屈折近点計，ダコモで測定）を有意に改善させると同時に，眼精疲労に伴う症状である「肩・腰がこる」，「眼がかすむ」などを改善させることが報告されている[4]。また健常成人を対象にして，VDT作業後の休息がもたらす調節機能の回復効果を調節微動解析装置（ニデック社 AA-1）で検討した試験において，AXは調節機能に影響を及ぼし，調節疲労の回復過程に働きかけ，疲労を速やかに取り除く作用があることが示唆されている[6]。これらの試験の多くは，眼のピント合わせのための調節力が比較的保持されている20歳後半から30歳後半の被験者を対象に行われているが，今回，老視を有する中高齢者を対象に，AXの調節機能と自覚症状に及ぼす影響を検討した。トライイリスC9000を用いて縮瞳率を算出して調節機能を評価し，自覚症状に及ぼす影響については被験者のアンケートにより調査した。

老視は，遠近のピント合わせをするための調節力が加齢により低下し，近方にピントが合わせづらくなった状態であり，40歳代から徐々に進行すると言われている。近くのものが見づらい，眼が疲れる，肩こり，眼が重い，頭重感，頭痛などが症状として現れる。今回の試験の対象者は46～65歳（平均54歳）の被験者で，22名の被験者のうち全員が「眼が疲れる」，20名が「近いところが見えにくい」，19名が「肩・腰がこる」，18名が「眼がかすむ」の症状を訴えており，典型的な老視を有する中高齢者が試験に組み入れられたと考えられる。

裸眼視力に対しては，既に報告されている試験においてもAXの影響はないとされており，今回の試験においても有意な変化はみられなかった。

調節機能はトライイリスC9000を用いて縮瞳率を算出して評価したが，この機器を用いると，近見時の調節による輻輳反応と縮瞳反応の変化を両眼開放化の生理的状態で，簡便な操作により測定することができる[15]。老視の検査（調節機能検査），VDT作業など眼精疲労による調節異常の検査，眼科手術前後の調節機能検査などに応用された報告が散見される[16~18]。今回の試験で左右眼において有意な縮瞳率の増加がみられたことより，AXが縮瞳，散瞳を司る瞳孔括約筋，散大筋の機能を活発化させた可能性が考えられる。AXは血流改善作用により毛様体筋を活発化させることが推測されているが[19]，同時に瞳孔括約筋，散大筋の血流を改善した可能性も考えられる。毛様体筋には輪状筋と縦走筋があり，それらは瞳孔括約筋，散大筋と神経支配が共通であることから協調運動をすると考えられている。毛様体筋機能が活発になれば近見瞳孔反応の縮瞳率が改善することも考えられる。

自覚症状のうち，「やや良くなった」以上と答えた被験者が多かった症状は，「眼が疲れる」，「近いところが見えにくい」，「眼がかすむ」，「肩・腰がこる」であった。「眼がかすむ」，「肩・腰がこる」については，疲れ眼を訴える成人を対象にした二重盲検試験においても有意に改善された症状である[4]。AXが瞳孔括約筋，散大筋の働きを活発化することにより（縮瞳率が増加し）瞳の動きが良くなり，焦点深度が深くなりピントが合いやすくなった結果が，自覚症状の改善に繋がった可能性が示唆される。

老視の対処は基本的には眼鏡の調製であるが，老視を有する中高齢者を対象にした今回の試験において，調節機能の増加と自覚症状の改善がみられたことより，AXの摂取は老視の進行した中高齢者においても，成人と同様に近業に伴う近視進行と老視進行を抑制し，眼精疲労を改善させる可能性が示唆された。

Ⅳ. ま と め

眼の疲れを訴える中高齢者（平均年齢53.9歳）22名を対象に，アスタキサンチン含有ソフトカプセルの調節機能と自覚症状に及ぼす影響を検討した。1日量6 mgのアスタキサンチンを4週間摂取させ，摂取前後でトライイリスC9000を用いて縮瞳率を測定した。摂取後に自覚症状の状態をアンケートにより調査した。その結果，アスタキサンチン摂取後に有意な縮瞳率の増加が認められ，アスタキサンチンは眼の疲れを訴える中高齢者においても調節機能を改善させ，老視に伴ういくつかの自覚症状を改善させる可能性があることが示唆された。

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