Original Article

The effect of dietary intake of coenzyme Q10 on skin parameters and condition: Results of a randomised, placebo-controlled, double-blind study

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Abstract

Coenzyme Q10 (CoQ10) is a natural constituent of foods and is also often used in both functional foods and supplements. In addition, it is a common ingredient of cosmetics where it is believed to reduce the signs of skin ageing. However, the existing data about the effect of dietary intake of CoQ10 on skin parameters and condition are scarce. To gain an insight into this issue, we conducted a double-blind, placebo-controlled experiment with 33 healthy subjects. Our objective was to investigate the effects of 12 weeks of daily supplementation with 50 and 150 mg of CoQ10 on skin parameters and condition. Study was conducted with a water-soluble form of CoQ10 with superior bioavailability (Q10Vital®). While the results of some previous *in vitro* studies showed possible protection in UVB response, we did not observe significant changes in the minimal erythema dose (MED). On the other hand, the intake of CoQ10 limited seasonal deterioration of viscoelasticity and reduced some visible signs of ageing. We determined significantly reduced wrinkles and microrelief lines, and improved skin smoothness. Supplementation with CoQ10 did not significantly affect skin hydration and dermis thickness. © 2016 BioFactors, 00(00):000-000, 2016

Keywords: *Coenzyme Q10; CoQ10; antioxidant; skin health; anti-ageing*

1. Introduction

Coenzyme Q10 (CoQ10) is an endogenous lipophilic compound, an essential component of the mitochondrial energy metabolism [1] and an effective antioxidant with a range of possible benefits for human health [2–4]. The presence of CoQ10 in the membranes of eukaryotic cells suggests its potential to act as an antioxidant and scavenge free radicals, preventing the activation of inflammatory signalling pathways [5]. The beneficial role of CoQ10 supplementation has been reported in various conditions, particularly in cardiovascular [6–8], neurodegenerative and mitochondrial conditions [9–11], diabetes [12], periodontal disease [13], and male infertility [14].

The human body biosynthesises CoQ10, but its skin levels, as well as its levels in other tissues, drop progressively with increasing age [15,16]. CoQ10 is also supplied to the organism by exogenous sources, for example, foods. The richest dietary sources are meat, migratory fish, nuts, and some oils, but in the diet of populations of Western countries these sources altogether contribute to just 3–5 mg CoQ10 per day [17]. Further, CoQ10 deficiency has been observed in some medical conditions [18], in persons with inadequate nutrition and in smokers [19]. It has also been shown that the endogenous synthesis of CoQ10 is inhibited by cholesterol-lowering statin drugs, which inhibit biosynthesis of mevalonate, and CoQ10 supplementation has therefore been suggested in such cases [20–22].

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Skin is the outermost human organ that is in direct contact with the environment and thus constantly exposed to external stress factors. In the skin, CoQ10 is found in both cells and skin surface lipids (SSL), a constituent of the stratum corneum, where it acts in combination with other substances as the skin's outermost barrier to oxidant assault [23,24]. CoQ10 is also crucial in maintaining mitochondrial activity in cells. It has been shown that CoQ10 levels in skin and skin surface lipids decline with age [15,24,25].

In the last decade, we have seen increased use of CoQ10 in health-related products. Even though in the European Union there are no authorized health claims regarding CoQ10 as a functional food ingredient, it is mostly used in products intended to support heart health. This can be explained by the fact that the strongest evidence is available for the beneficial role of CoQ10 supplementation in cardiovascular health [6–8] but, considering that studies were not performed on healthy population groups, such evidence cannot be used to substantiate health claims for foods [26]. On the market, CoQ10 is mainly used in food supplements [27], although it can also be found in functional foods. For example, CoQ10 was added as a functional ingredient to 3.5% of yoghurts sold in the Slovenian food supply in 2011 [28]. Recommended daily dosages in food supplements usually vary from 50 to 150 mg, however products with higher levels are also available.

In addition to such use, CoQ10 is also commonly added to cosmetics, chiefly due to its perceived ability to protect the skin from free radical damage and reduce signs of ageing. As shown by several *in vitro* experiments, CoQ10 is able to protect the skin from reactive oxidative species (ROS), induce the proliferation of skin fibroblasts, inhibit MMP-1 enzymes that degrade extracellular matrix components, accelerate the production of epidermal basement membrane components, reduce DNA damage triggered by UVA irradiation, decrease UVR-induced inflammatory response and lower levels of superoxide generation by ArNOX proteins [29–34]. There are also some studies showing beneficial effects of topical CoQ10 use on skin *in vivo*. Knott et al. very recently showed that topical application of CoQ10 raises its epidermal content in both SSL and deeper layers of the epidermis and improves the skin's antioxidant potential [25]. Improvement of the antioxidant potential of the skin by topical CoQ10 application was also shown by Vinson et al. [35]. Hoppe et al. showed that three months of topical CoQ10 application decreased wrinkle depth in human skin [36], but statistical data for these effects were not provided. A clinical trial involving 31 females demonstrated a reduction in wrinkle score after using CoQ10 cream for 5 months [30]. A clinical trial by McDaniel with idebenone (a synthetic CoQ10 analog) lotion showed an increase of collagen I expression and improvement in skin roughness, wrinkles and fine lines, but a vehicle control group was lacking [37].

Supported by this evidence, along with very strong marketing campaigns of the cosmetics industry, CoQ10 has also become an interesting functional food ingredient in so-called *beauty products*, formulated to support skin health. However, the existing data about the effect of dietary intake of CoQ10 on skin parameters and condition is scarce [32]. Passi et al. showed that joint oral and topical use of CoQ10 in combination with vitamin E is able to raise CoQ10 levels in skin and reduce wrinkle depth [38], but to our knowledge no reports in the scientific literature assess the efficiency of dietary CoQ10 alone. In comparison to topical application, where skin barrier limits penetration of the CoQ10, oral intake could deliver this compound more efficiently into the dermis, skin layer responsible for skin elasticity and firmness among others.

To gain an insight into the effect of dietary intake of coenzyme Q10 on skin parameters and condition, we conducted a double-blind, placebo-controlled experiment with 33 healthy volunteers. Our objective was to investigate the effects of 12 weeks' dietary supplementation CoQ10 on erythema response to UVB, visible signs of ageing—wrinkles and skin microrelief, skin hydration and elasticity, and dermis condition.

2. Methods

2.1. Design of the Study

2.1.1. Subjects

Thirty-three healthy Caucasian female volunteers, ranging in age from 45 to 60 years (mean age 52.6 ± 4.2 (SD)) with Fitzpatrick skin phototypes II and III were enrolled in the study after providing written consent. Inclusion criteria were signs of skin ageing (mimic wrinkles/poor skin tone/visual dryness), photo-aged skin on the face, and expression of mimic wrinkles. Exclusion criteria were pregnancy or breastfeeding, a known or suspected allergy to any ingredient of the tested products, high blood cholesterol and use of cholesterol-lowering medicines, diagnosed diabetes, thyroid disease, inflammatory skin diseases, regular use of dietary supplements (including products with added CoQ10) in last 6 months preceding study entry, invasive (Botox injections, hyaluronic acid fillers, needle rollers, needle mesotherapy, etc.) and noninvasive (radiofrequency, electrotherapy, ultrasound therapy, etc.) rejuvenation treatments in last 6 months prior to study entry, the use of cosmetic products containing CoQ10 in last 6 months preceding study entry, and gluteal hyperpigmentation. Subjects were also asked not to change their routinely used skin care regime on the test sides during the entire study period. Further, subjects were asked to continue their normal dietary habits. Additional dietary supplements, sunbathing and use of tanning machines were not allowed during the 12-week intervention trial. Consistent with the principles laid down in the Declaration of Helsinki, all subjects provided signed informed consent before recruitment. The study was approved by the Ethics Committee of the Higher School of Applied Sciences, and included in the ClinicalTrials.gov register under record NCT02604641.

Subjects were randomly assigned to either: (a) a placebo group (mean age 52 ± 4 years); (b) a low-dose group (LD group; 54 ± 4 years) receiving 50 mg of CoQ10/day; or (c) a high-dose group (HD group; mean age 52 ± 5 years) receiving 150 mg of CoQ10/day; with 11 subjects per group.

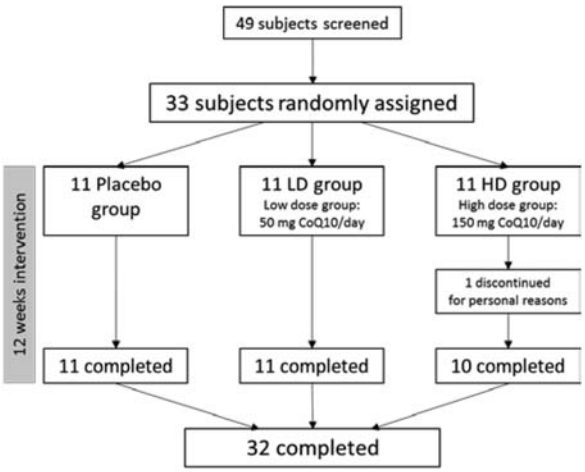

FIG 1 *Flow diagram showing the study design and subjects' assignment and progression through the trial.*

Out of 33 subjects enrolled in the study, 32 completed the entire 12-week trial (HD group: 10 subjects, LD and placebo group: 11 subjects each), there was one drop-out in the HD group before regular check after 6 weeks.

2.1.2. Intervention

All subjects consumed 5 mL of a syrup daily for 12 weeks. The placebo group received an aqueous syrup formulation without CoQ10 (placebo), the LD group received test syrup with 50 mg of CoQ10 per 5 mL, and the HD group received test syrup with 150 mg of CoQ10 per 5 mL (Fig. 1). To enable the production of aqueous syrup with CoQ10, a water-soluble form of CoQ10 was used in the formulations (Q10Vital® as used in Quvital® food supplements, Valens Int. d.o.o., Slovenia) [39,40]. Improved bioavailability of this constituent was previously reported [41]. All three syrups were formulated and produced by Valens Int. d.o.o. Syrup base contents were sugar, water, apple juice concentrate, sodium benzoate (preservative), citric acid, and apple flavor. In test syrups CoQ10 (Q10Vital®) was added to this base, while placebo syrup was coloured with food colouring agents (E102, E110) and thickened using modified starch to achieve organoleptic characteristic, comparable to test syrups. No other known anti-aging ingredients but CoQ10 were employed in the tested formulation, and therefore, any increase in efficacy over the placebo could be reasonably attributed to the CoQ10. To assure the proper CoQ10 concentration, all three variations of the syrup samples were also sent for testing to an independent laboratory (Chelab S.r.l, Resana, Italy), where the CoQ10 concentration was determined using standard high-performance liquid chromatography [27]. To monitor subjects' compliance with the instructions the subjects were asked to record daily intake of a syrup; diaries were checked at their visits after 6 and 12 weeks. Subjects were also asked to record any failure to comply with the instructions. At the last evaluation term they were required to return leftover test products.

2.2. Assessments

Regular checks of the subjects were carried out three times during the study: at the baseline (week 0), after 6 weeks (week 6) and after 12 weeks of supplementation (week 12) and Visioface images of the face were recorded at those times. Changes of dermis ultrasonic echogenicity and thickness as well as skin surface parameters (hydration, viscoelasticity) were measured on the face at week 0 and week 12. The minimal erythema dose (MED) was determined on a gluteal area at week 0 and week 12. Wrinkle area fraction measurements were performed on the face using the Visioface CSI system and additionally assessed according to the Lemperle scale at week 0 and week 12. Results were obtained during a period of colder outside temperatures and low sun exposure from November 2014 to January 2015; average monthly temp. 8.8°C, 3.9°C, and 2.8°C, respectively. All measurements were carried out on subjects lying in a room with a temperature of 20–25°C and relative humidity 40–60%, except the Visioface imaging was done in a sitting position. Measurements started after a 30 Min acclimatization period in the same atmospheric conditions. Subjects were advised to clean their face at least 2 H before the time of measurement and to not apply any cosmetic products on their face 2 H or less before the measurement.

2.2.1. Skin viscoelasticity and hydration measurements, ultrasound measurements of dermis thickness and density

Viscoelasticity measurements were performed on a predetermined position of the right cheek using a Cortex Technology DermaLab Combo SkinLab elasticity probe (Cortex Technology, Hadsund, Denmark). The measurement gives results in MPa.

Hydration measurements were performed on a predetermined area of the right cheek using a Cortex Technology DermaLab Combo SkinLab hydration probe, which operates on the conductivity principle. Eight consecutive measurements were conducted and the result for each subject is the average of them. The measurement gives results in μS.

Ultrasound measurements of dermis thickness and density were performed using a Derma-Lab® Combo SkinLab USB 20 MHz high-resolution ultrasound scanner probe (Cortex Technology, Hadsund, Denmark). A constant gain curve was applied for each volunteer and dermis thickness and intensity (density) were determined as published elsewhere [42]. Measurements were carried out on a predetermined position on the right cheek. Skin thickness is measured in μm and intensity as a 0–100 score.

2.2.2. Photography, wrinkle measurements and evaluation, skin surface evaluations

High-resolution lateral (left and right) and frontal images of the face (10 Mpx) were taken using the VisioFace Quick system (Courage + Khazaka electronic GmbH, Germany), with a constant distance from the camera in standardized white light after the subject had placed her face to the front or to the side in a light facial booth. The diodes illuminate the face evenly.

The camera and lights were both software-controlled and immediately ready for use. Because the topography of the skin varies significantly within a few millimeters, the exact location of the face was obtained by carefully comparing details on the face with the baseline image, repositioning the face position in the apparatus in order to obtain a precisely exactly matching picture of the face. The wrinkle area fraction (wrinkle area divided by the assessment area) of periorbital wrinkles was measured for each subject at the baseline and after 12 weeks using the VisioFace CSI software.

Wrinkle assessment was performed for six different wrinkle types in different face areas using frontal and lateral Visioface images by experienced professionals at week 0 and week 12 according to the Lemperle scale (0–5) [43]. When evaluating each wrinkle type, only those subjects who had expressed wrinkles of the observed type at the baseline were evaluated.

Evaluation of subjects' skin smoothness and microrelief was also conducted at week 0 and week 12 by a comparison of the Visoface images of the face (frontal, left lateral, and right lateral). The 96 pairs of photographs were assessed using a 3-grade scale (−1: deterioration, 0: no change, +1: improvement) by experienced professionals. Photographs for week 0 and week 12 were presented in a blind and randomized sequence for each subject.

Skin firmness was assessed by self-evaluations at week 0 and week 12 using a 3-grade scale (−1: deterioration, 0: no change, +1: improvement).

2.2.3. MED

At the baseline and after 12 weeks, the minimal UVB erythema dose (MED) was assessed using an automated MED Tester (Dermalight® 80 MED Tester, Dr Hoenle Medizintechnik GmbH, Germany; UVB 280–320 nm). Increasing UV doses (exact dosages depending on the individual's skin phototype following the Fitzpatrick classification) were applied on a gluteal area through means of 10 small round apertures within the MED tester.

MED readings were taken 24 H after the application of UV, with the MED being defined as the lowest dose of UV resulting in visible erythema of the skin. The UV dose is given in J/cm^2. No application of skin care products on the gluteal area 12 H before and 24 H after the UV application was allowed.

2.3. Statistical Methods

Data were analyzed using the XLStat statistical software package (Addinsoft, Barcelona, Spain, version 2016.02.28719). All the data measured are shown as the mean ± standard error (SE). Paired *t*-test or the Wilcoxon signed rank test (for nonparametric variables) was used to compare baseline values and values during the supplementation in each group. The mean percentage change from the baseline was determined. For comparisons between groups the data were analyzed using one-way ANOVA with Tukey-Kramer post-hoc test or (for nonparametric variables) Kruskal-Wallis test with Dunn post-hoc test to determine significant differences between groups. $P < 0.05$ was considered as statistically significance.

3. Results and Discussion

Out of the 33 subjects enrolled in the study, 32 completed the entire 12-week trial. One subject in the HD group withdrew before regular check after 6 weeks for nonrelated reasons, and the results for 32 subjects were analyzed. None had to leave the study because of adverse events or serious side effects. No side effects of any kind were reported.

3.1. MED

Sunburn (*UV-induced erythema*) is a result of excessive exposure of the skin to sunlight, particularly UVB irradiation. Photochemical reactions in the skin lead to increased concentrations of reactive oxygen species (ROS), which stimulate the inflammatory pathways [44]. UV-induced erythema starts to develop within a few hours, peaking about 18–24 H post exposure. MED is defined as the lowest dose of UV producing detectable visible erythema of the skin 24 H after the exposure [45,46]. It is a measure of individual sensitivity to erythematogenic UV exposure. It varies between individuals and depends on the actual endogenic protection. MED measurements were used to show *in vivo* photoprotective effects for a number of dietary antioxidants, for example, ascorbate, carotenoids, and tocopherols [46]. While no such data are available for CoQ10, *in vitro* studies have shown that CoQ10 is able to decrease UV-induced damage and inflammatory response [29,47,48]. On the other hand, no photoprotective effects of CoQ10 were observed for in vivo topical applications [49].

In our study, the MED was slightly reduced from the baseline at the end of the study period in the placebo group (placebo: 0.64 J/cm^2 ± 0.05 at the baseline vs. 0.62 J/cm^2 ± 0.04 at week 12, $P = 0.64$) while it was slightly increased in both CoQ10 groups (LD group: 0.69 J/cm^2 ± 0.08 at the baseline vs. 0.72 J/cm^2 ± 0.06 at week 12, $P = 0.36$; HD group: 0.66 J/cm^2 ± 0.06 at the baseline vs. 0.70 J/cm^2 ± 0.06 at week 12, $P = 0.32$), but those changes were not significant in either of the groups (Fig. 2). An intergroup comparison between the placebo, the LD or HD groups also did not show any significant differences ($P = 0.49$). Consequently, based on these results we could not confirm an *in vivo* anti-inflammatory effect of CoQ10 as previously shown for UV response in *in vitro* studies [29,47,48]. It should be noted that while conducting a study with a higher number of subjects or a longer supplementation period might result in significant changes in MED, based on the results reported herein the expected increase in MED would still be minor. Moreover, the increase in the dosage of CoQ10 supplementation did not have an important influence on MED. One reason that CoQ10 did not provide photoprotective effects could lie in its sensitivity to UV exposure, which has previously been shown on a skin model [50].

3.2. Wrinkle Assessments

The effect of CoQ10 supplementation on wrinkle expression was assessed in the periorbital area. Measurements of periorbital wrinkle area fraction show no significant change in the placebo group (0.580 ± 0.065 baseline vs. 0.579 ± 0.065 at

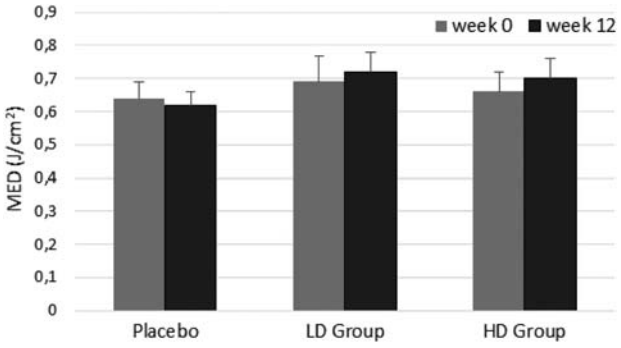

FIG 2 *Minimal erythema dose (MED, mean ± SE) at the baseline and after 12 weeks of CoQ10 supplementation. No significant change was detected in either the placebo or the CoQ10 groups.*

week 12, $P = 0.92$) while there was a significant improvement in both CoQ10 groups (Fig. 3). In the LD group, wrinkle area fraction was reduced from 0.575 ± 0.077 at the baseline to 0.509 ± 0.074 at week 12 ($P = 0.02$) and in the HD group it was reduced from 0.492 ± 0.070 at the baseline to 0.442 ± 0.070 at week 12 ($P = 0.02$). The intergroup comparison of the LD and HD groups also shows a significant reduction in the wrinkle area in comparison to the placebo ($P = 0.04$ for the LD and 0.04 for the HD group vs. placebo) (Fig. 3). However, there is no significant difference in relative change of the wrinkle area fraction over the 12-weeks of supplementation between the HD and LD groups ($P = 0.99$).

The influence of CoQ10 on periorbital wrinkles and lines can be observed in Fig. 4 where the periorbital area of two subjects from the LD (Fig. 4, 1a, 1b) and HD group (Fig. 4, 2a, 2b) before the CoQ10 supplementation (Fig. 4, 1a and 2a) and after 12 weeks of supplementation (Fig. 3, 1b and 2b) is shown. After 12 weeks of supplementation, wrinkles are visibly reduced and an improvement in microrelief lines and smoothness can also be observed.

To provide further insight into the anti-ageing effects of CoQ10, we performed an expert assessment of wrinkles of different types in different face areas according to the Lemperle scale. Table 1 provides before-after comparisons for subjects with expressed wrinkles in the selected area at the baseline. In the placebo group, no significant changes in wrinkle expression were observed for any of the six evaluated wrinkle types. While we did not observe a dose-response relationship when wrinkle expression was assessed (using wrinkle area fraction measurement) in the periorbital area (Fig. 3), the inclusion of other facial areas showed a notable improvement when a higher dose of CoQ10 was used. In addition to significant improvements of periorbital (PO) lines in both the LD and HD groups (in comparison to week 0; $P < 0.05$), improvements in nasolabial folds (NL), corner of the mouth lines (CM) and upper radial lip lines (UL) were noted only in the HD group ($P < 0.01$, <0.01 and <0.05, respectively).

3.3. Dermis Thickness and Density

In the placebo group, the average dermis thickness remained without significant change (mean 1461 ± 42 μm at the baseline vs. 1453 ± 43 μm at week 12; $P = 0.42$) as determined with ultrasound imaging of the dermis. However, there was also no significant change of dermis thickness in either CoQ10 group (LD group: 1494 ± 51 μm at the baseline vs. 1510 ± 47 μm at week 12; $P = 0.31$, HD group: 1432 ± 57 μm at the baseline vs. 1448 ± 53 μm at week 12; $P = 0.16$). The dermis intensity score was also not significantly changed for any of the groups (placebo: mean 27 ± 2 at the baseline vs. 30 ± 3 at week 12; $P = 0.12$; LD group: 28 ± 2 at the baseline vs. 26 ± 2 at week 12; $P = 0.12$; HD group: mean 26 ± 2 at the baseline vs. 28 ± 3 at week 12; $P = 0.23$). As dermis intensity is related to the amount of properly structured dermal proteins, for example, collagen and elastin (density), we cannot conclude that CoQ10 promoted the synthesis or reduced degradation of structural proteins as shown in some *in vitro* studies [29,30,32]. Yet we should note that, due to large interpersonal variations in the baseline dermis intensity, the study was under-powered to show the effect; a study with over 100 subjects per group would be needed for clear conclusions. Supplementation over a longer period would also probably be beneficial.

3.4. Elasticity and Hydration

The measurement of skin viscoelasticity revealed a significant 24.5% decrease in the placebo group after the 12-week study period ($P = 0.03$) but, on the other hand, viscoelasticity was stable in both CoQ10 groups as there was no significant change in viscoelasticity in either of them ($P = 0.69$ and 0.24 for the LD and HD groups, respectively) as shown in Table 2. Inter-group differences of viscoelasticity changes were significant between the placebo and both the LD group ($P = 0.03$) and the HD group ($P = 0.03$). It is worth noting that the study

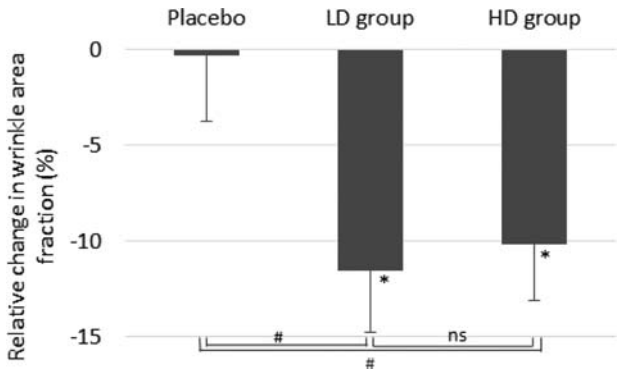

FIG 3 *Relative changes in periorbital wrinkle area fraction for the placebo, LD and HD groups after 12 weeks of CoQ10 supplementation. Data shown as relative change of wrinkle area fraction (± SE) in comparison to baseline values. *$P < 0.05$ significant difference for a comparison of week 12 to week 0; $^{\#}P < 0.05$ significant difference between groups; ^{ns} no significant difference between groups.*

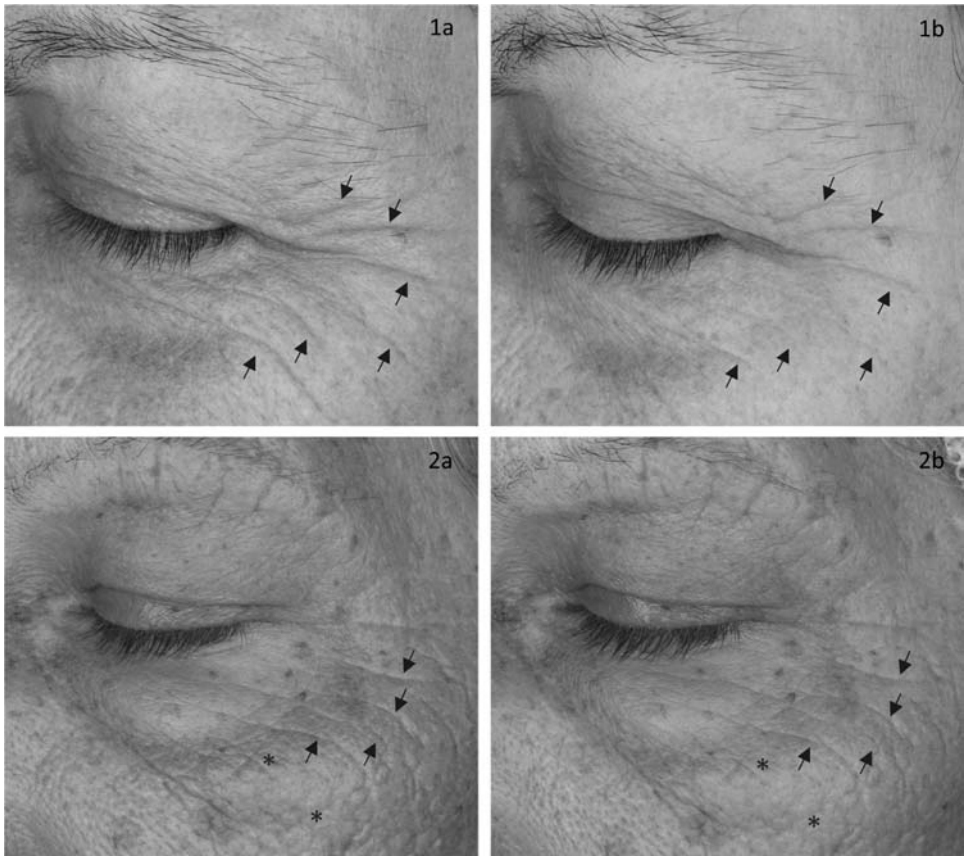

FIG 4 *Images show the periorbital area of two subjects (both 60 years old) from the LD group (1a, b) and HD group (2a, b) before the CoQ10 supplementation (week 0, images 1a and 2a) and after 12 weeks of supplementation (images 1b and 2b). Arrows mark the wrinkles that visibly improved; * marks the area where improvement of smoothness and microrelief lines can be observed.*

was conducted over the late autumn and winter season simultaneously for all three groups. As several studies have confirmed dramatic changes in viscoelasticity and other skin surface parameters [51,52] during colder winter months, the obtained results support the positive effects of oral CoQ10 supplementation for limiting negative viscoelasticity seasonal changes during winter.

In contrast, no significant changes in skin hydration (Table 2) were detected in any of the groups. While the dermis is mostly responsible for skin elasticity, the hydration level of the skin relates to the hydration level of the epidermis layer and is therefore not correlated.

3.5. Improvement of Skin Smoothness, Microrelief, and Skin Firmness in the HD and LD Groups

There was an improvement in skin smoothness as determined by the expert evaluation in both groups receiving CoQ10, namely in 70% of subjects in the HD and 82% in the LD group,

TABLE 1 ***Wrinkle assessment according to the Lamperle scale (0–5) of HF, horizontal forehead lines; GF, glabellar frown lines; PO, periorbital lines; NL, nasolabial folds; CM, corner of the mouth lines; UL, upper radial lip lines. Results are given as average score ± SE***

	HF		*GF*		*PO*		*NL*		*CM*		*UL*	
Week	*0*	*12*	*0*	*12*	*0*	*12*	*0*	*12*	*0*	*12*	*0*	*12*
Placebo	1.3 ± 0.2	1.4 ± 0.2	2.1 ± 0.3	2.1 ± 0.3	2.5 ± 0.2	2.5 ± 0.2	2.0 ± 0.4	2.0 ± 0.4	2.0 ± 0.4	2.0 ± 0.4	1.9 ± 0.4	1.9 ± 0.4
LD Group	2.1 ± 0.4	2.0 ± 0.3	2.9 ± 0.4	3.0 ± 0.4	2.8 ± 0.3	2.4 ± 0.3*	2.9 ± 0.4	2.8 ± 0.4	2.5 ± 0.4	2.4 ± 0.4	1.8 ± 0.3	1.7 ± 0.3
HD Group	1.3 ± 0.2	1.0 ± 0.2	2.6 ± 0.5	2.6 ± 0.5	2.2 ± 0.4	1.7 ± 0.3*	2.8 ± 0.4	2.1 ± 0.5**	2.6 ± 0.4	2.1 ± 0.5**	1.4 ± 0.3	0.6 ± 0.3*

*$P < 0.05$; **$P < 0.01$: Significantly different from week 0.*

TABLE 2 ***Skin viscoelasticity and hydration for the placebo, LD and HD groups at the baseline (week 0) and after 12 weeks of CoQ10 supplementation***

		Week 0	*Week 12*	*% change*	P-*value**
Viscoelasticity (MPa)	Placebo	2.15 ± 0.28	1.63 ± 0.23	−24.5	0.03
	LD Group	1.87 ± 0.28	1.96 ± 0.14	4.8	0.69
	HD Group	1.80 ± 0.11	1.97 ± 0.17	9.4	0.24
Hydration (μS)	Placebo	221 ± 17	185 ± 16	−16.3	0.06
	LD Group	193 ± 15	178 ± 16	−7.9	0.17
	HD Group	233 ± 19	201 ± 22	−13.7	0.16

**Comparison week 12 to week 0.*

while in the placebo group there were no subjects with an improvement in skin smoothness. Similar trends were observed for microrelief lines as they became notably less expressed in 64%, 60%, and 9% of subjects in the HD, LD and placebo groups, respectively.

Average scores of the expert evaluation for changes in skin smoothness and microrelief lines between week 0 and 12 are presented in Fig. 5. For both skin smoothness and microrelief, the changes between the placebo and LD, and the placebo and HD groups were statistically significant, while the difference between the LD and HD groups was not significant. It should be noted that subjects also reported (by self-evaluation) an improvement in skin firmness in 70%, 36%, and 18% of subjects in the HD, LD, and placebo groups, respectively.

3.6. Study Limitations

It should be noted that some baseline skin parameters are quite variable and it would therefore be beneficial to perform a study on a higher number of subjects to allow clearer conclusions regarding some parameters. For example, the study was under-powered for dermis parameters (intensity, thickness). Supplementation over a longer period and several seasons would also be worth testing as this study was conducted during winter, and also, 12 weeks is quite a short time to detect nutritional effects on skin, considering the length of the skin regeneration cycle. Considering this, a longer study period would also provide valuable insights into dose-response relationships. While we were unable to show such a relationship in our study, such an effect might (or might not) be observed if supplementation were to be done over more skin cycles. It should also be noted that with the intention to minimize the study's invasiveness and to assure high compliance rates, this study was conducted without measuring plasma CoQ10 levels. Due to inter-individual differences in CoQ10 absorption after supplementation [41], data on the plasma CoQ10 levels in individuals might also explain some subject-to-subject differences in this study, and therefore provide more direct evidence for understanding the relationship between coenzyme Q10 and skin parameters after supplementation.

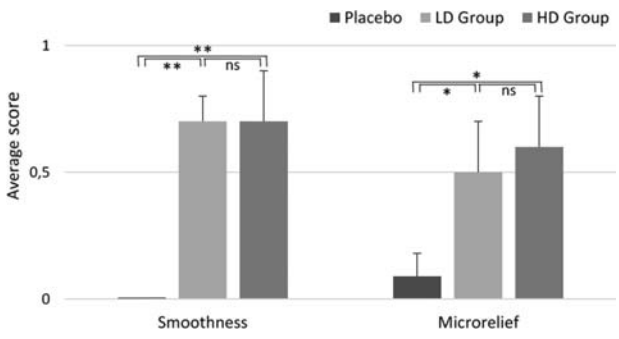

FIG 5 *Average score for changes in smoothness and microrelief lines after 12 weeks of CoQ10 supplementation as determined by the expert evaluation (−1: deterioration, 0: no change, +1: improvement). *P < 0.05, **P < 0.01 significant difference; ns no significant difference between groups.*

4. Conclusions

In the present study, the administration of a dietary supplement containing CoQ10 over a 12-week period showed several anti-ageing effects as it reduced wrinkles, improved skin smoothness and microrelief as well as skin firmness. It also helped the skin combat seasonal changes since it prevented negative viscoelasticity seasonal changes during winter. The influence of the CoQ10 dose on response was observed only in the expert assessment of wrinkles. While improvement of periorbital wrinkles was comparable for both CoQ10 groups, in the HD group an additional improvement of wrinkles in other facial parts (nasolabial folds, corner of the mouth lines and upper radial lip lines) was observed. There was no significant change of those wrinkles in the LD or placebo group. We were

unable to show the effect of the supplementation on skin hydration, dermis thickness and density. The results also showed that CoQ10 actually offered little to no photo protection since it was unable to reduce UVB-induced inflammation.

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