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Can dietary intake influence perception of and measured appearance? A Systematic Review

Dietary intake and appearance

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Abbreviations

RCT: Randomized control trial

BMI: Body mass index

ABSTRACT

Appearance-based interventions have had some success in reducing smoking and sun exposure. Appearance may also motivate dietary behavior change if it was established that dietary improvement had a positive impact on appearance. The aims of this review are to evaluate the current evidence examining the relationship between dietary intake and appearance and to determine the effectiveness of dietary interventions on perceived or actual appearance. An electronic search of English language studies up to August 2012 was conducted using Cochrane, MEDLINE, Embase, CINAHL, Web of Science, SCOPUS and PsycINFO databases. Studies that included participants aged ≥ 18 years, that observed or altered dietary intake from actual food or dietary supplement use and assessed appearance-related outcomes were considered eligible. Data from 27 studies were extracted and assessed for quality using standardized tools. Nineteen studies were assessed as being of "positive" and four of "neutral" quality. All observational studies (n=4741 participants) indicated that there was a significant association between various aspects of dietary intake and skin coloration and skin aging. The majority (16 studies, 769 participants) evaluated the effect of dietary supplements on skin appearance amongst females. Only one study examined the effect of actual food intake on appearance. Significant improvements in at least one actual or perceived appearance-related outcome (facial wrinkling, skin elasticity, roughness and skin color) following dietary intervention were shown as a result of supplementation. Further studies are needed in representative populations that examine actual food intake on appearance, using validated tools in a well-designed high quality RCTs.

Keywords: diet, appearance, fruit, vegetables, skin

1. INTRODUCTION

Poor dietary intake is one of the most important risk factors for preventable disease and premature mortality[1]. Poor nutrition is responsible for around 16% of the total burden of disease worldwide and is associated with excessive intake of energy dense foods, saturated fat and added refined sugar or salt [1]. Improving nutrient intake promotes good health, well-being and reduces the risk of many chronic diseases [1]. For instance, consuming an adequate amount of fruit and vegetables in our diet has been shown to reduce the risk of excess weight gain, type 2 diabetes, cardiovascular disease, and specific cancers [1-3]. Despite the benefits of consuming adequate amounts of fruit and vegetables, intake of this food group is low amongst the adult population worldwide and is identified by the World Health Organization as among the top 10 risk factors for global mortality [4]. Only 2.2% of men and 3.5% of women [5] in the United States meet their caloric-specific MyPyramid fruit and vegetable recommendations. In the United Kingdom 31% of adults meet their current combined fruit and vegetable intake recommendation of "5-a-day" [6]. In Australia, only 5.5% of adults meet guidelines (2 serves of fruit and 5 serves of vegetables), with 18-34 year-olds least likely to meet recommendations (3.4%) [7].

Current efforts to improve an individuals' diet often involves behavioral interventions that aim to improve fruit and vegetable intake. Several reviews have evaluated the efficacy of such interventions [8-10]. The most recent was conducted by Thomson et al. in 2011 [10] who evaluated behavioral interventions to improve fruit and vegetable intake among individuals without pre-existing health conditions that were published between 2005 and 2010. Based on the 34 studies included, the mean increase in servings per day of fruit and vegetable post intervention was 1.13 in adults and 0.39 in children [10]. This review

concluded that in order for individuals to achieve recommended fruit and vegetable intake targets, additional approaches are required as the best available evidence indicates that it cannot be achieved solely by existing behavioral interventions [10].

In order to consider other approaches to promote dietary behavior change, an understanding of what motivates individuals to change their health behaviors is required. A recent study conducted by LaRose et al [11] compared motivating factors for weight loss and weight loss behaviors of young adults (18 – 35 years) versus older adults (36-50 years) who had been successful in long-term weight loss [11]. Young adults rated "improving your appearance", "improving social life" and "wanting to feel better about yourself" more important than "health concerns", which was rated as most important amongst the older adults [11]. These findings are consistent with a recent survey of UK adults who were asked questions on both the importance of "looking good" and the importance of "health" in relation to their diet [12]. The results indicated that health was of highest importance amongst the older female age group, whilst younger females felt more motivated to eat healthily based on concerns about their appearance. The researchers concluded that interventions to promote healthy eating and improve diet quality among young women should focus on appearance rather than health [12]. Therefore, appearance-based interventions may be a potential new approach to promote dietary behavior change, particularly among younger adults.

Appearance-based interventions have had some success in motivating behavior change, predominantly for smoking [13] and sun exposure behaviors [14]. Photographs demonstrating the effects of ultraviolet light exposure on facial images have been shown to precipitate a

sustained period of behavior change in sun tanning practices [14]. Images visualizing the adverse effects of smoking on facial skin wrinkling and oral disfigurement have also motivated smoking cessation [13]. Before appearance-based interventions are developed for dietary behavior change we must first establish that what we eat influences our appearance. There is some evidence to suggest a relationship between dietary intake and appearance but existing evidence has not been systematically synthesized. Therefore, the primary objectives of this review are to evaluate recent evidence examining relationships between dietary intake and physical appearance and to determine the effectiveness of dietary interventions on perceived or actual physical appearance. For the purpose of this systematic review Cochrane, Medline, Embase, CINAHL, Web of Science, Scopus and PsycINFO databases were searched using specific keywords for relevant studies published until August 2012 and by also reviewing the reference lists from retrieved articles. Study quality was assessed and data extracted using standardized appraisal tools. Data was analyzed using narrative summary.

2. METHODS FOR THE SELECTION OF LITERATURE REVIEWED

This review followed all PRISMA statement guidelines except for protocol publication.

2.1 Eligibility Criteria

Types of participants

Studies that included individuals aged 18 years and older were included. Studies in which participants had a history of eating disorders or chronic medical conditions or who were pregnant were excluded.

Types of interventions/exposure

Both experimental and observational studies that provided a dietary intervention or evaluated participants' exposure to dietary components respectively were included. Included studies had to report dietary intake from either actual foodstuffs/food groups or dietary supplement use or both. The definition of dietary intake for the review was necessarily broad due to the researchers' awareness that a low number of studies had specifically investigated the relationship between food intake and appearance.

Outcome measures

Studies that assessed physical appearance as the primary outcome were considered. For the purpose of this review, appearance is defined as either an individual's or observer's perception of physical appearance or an objective measure of an outward aspect of physical appearance, including skin color and tone and body shape.

Studies that examined the relationship between BMI and body image or shape were not included.

2.2 Search Strategy

A three-step search strategy was used for this review to identify published studies in the English language up to and including 2nd August 2012. An initial limited search was conducted in MEDLINE and CINAHL followed by analysis of titles, abstracts, and index terms used to describe articles. All identified keywords and index terms were used in a second search across the following databases: The Cochrane library, MEDLINE, PRE-MEDLINE, Embase, CINAHL, Web of Science, SCOPUS and PsycINFO. The reference lists of all included articles were also searched for additional relevant studies.

Search terms

The search terms were divided into two groups: (i) dietary intake (e.g. nutrition, fruit, vegetables, carotenoid*, diet quality, dietary supplement*) and (ii) appearance (e.g. beauty/ vanity /appearance, skin pigmentation, complexion, skin color/ skin color, skin coloration/ skin coloration, skin tone, attractiveness, self-image, body shape, body image, self-esteem, self-perception, self-concept.) The Boolean phrase "AND" was used between groups and "OR" for within groups.

2.3 Study Selection

Following the search, duplicates were removed and articles were screened and identified for relevance to the review based on the title, abstract and description/MESH headings by two reviewers. Endnote was used for data management. The full article for studies that met the inclusion criteria were retrieved and examined independently by two reviewers to confirm inclusion. If it was unclear from the abstract whether the study met the inclusion criteria, the full article was also retrieved for clarification. If a disagreement occurred as to the inclusion or exclusion of a study a resolution was reached through a third independent reviewer.

2.4 Critical Appraisal

Two independent reviewers assessed the included articles for methodological quality using the Academy of Nutrition and Dietetics Quality Criteria Checklist [15]. Studies were appraised as 'positive' if they answered yes to all of the following criteria: selection of study participants "free from bias", methods of assigning subjects/participants to groups described and unbiased "comparable study groups", "interventions were described in detail", were the primary and secondary "outcomes valid and reliable" plus at least one additional yes from the other six items [15]. If six or more of the ten items were answered 'no' the study was labeled 'negative'. Studies were labeled 'neutral' if neither of these criteria were met [15].

2.5 Data Extraction

Data was extracted from the included studies using a standardized form developed by the authors that included study characteristics such as number of participants, study duration, exclusion/inclusion criteria, retention rates, appearance outcomes and measures, results and exposure. One reviewer extracted all of the data which was cross-checked by the second reviewer.

3. INTEPRETATION OF DATA

3.1 Description of Studies

The search identified 11,678 articles (Figure 1). Following the elimination of duplicates and assessment of the abstract for eligibility, 59 full text studies were retrieved of which 27 studies were included in the review. The primary reasons for exclusion on review of full text articles (after abstract/full article retrieval) were; not having relevant outcomes reported (n=30), failure to meet participant eligibility criteria (n=5) and not being an observational or experimental study (n=3).

Of the included studies, nine observational studies evaluated the relationship between dietary intake and appearance, of which four were case studies, four were cross-sectional studies and one was a prospective cohort study. There were 18 experimental studies that evaluated effectiveness of dietary interventions on physical appearance outcomes, of which 17 were RCTs and one a pre-post single-arm study. The 27 studies were published between 1985 and 2012 and were conducted in 14 countries with the majority in the USA (n=7) and Europe (n=14).

3.2 Association between dietary intake and appearance

Study characteristics, critical appraisal and results of the included observational studies are summarized in Tables 1, 2, and 5 respectively. The total number of participants across all observational studies was 4741, of which 94% were female. The mean number of participants across all studies was 527 (Range 1-4025). The age range of participants was 18 to 104 years.

Five observational studies were critically appraised for quality with all assessed as being 'positive' (Table 5). The observational studies (n=5) had comparable study groups, participant selection free from bias and measured outcomes using valid and reliable methods. No studies reported or used blinding, which could introduce bias. The four case reports were not assessed for their quality as there is no current tool for this study type and their methodological quality is low. Results from these four studies have been interpreted with caution.

Appearance outcomes were grouped by the outcomes of skin coloration (n=6), skin aging (n=2), and body image (n=1). The majority of the dietary intake variables examined in the included studies were reported as fruit and vegetable consumption (n=5), others included dairy, meat, fish oils, fats and sugar.

3.3 Relationship between dietary intake and appearance outcomes

Skin Coloration

All four case reports (Table 1) [16-19] reported orange coloration of the palms, soles of feet and face due to excessive consumption of foods, including kaki fruit (1kg daily) [16],nori rolls (50 sheets daily) [17], raw carrots (2kg daily) [18] and tomatoes (0.5kg daily) [18] , or nutrient supplements containing carotene (4410ug/dl daily) [19]. Skin coloration was reported to gradually subside after reducing or ceasing intake in each of the four case reports.

One study [20] reported significant associations between objectively measured skin yellowness (CIE Lab color space b* values) at multiple body sites with changes in fruit and vegetable intake over six weeks (Table 2). In addition, it was found that diet-linked changes in spectrophotometer-assessed skin reflectance were correlated with absorption spectra of beta-carotene, alpha- carotene and lycopene [20]. Another study [21] found that individual's with higher fruit and vegetable intakes had increased skin yellowness b*values.

Skin Aging

Two studies [22],[23] examined the relationship between nutrient intakes and skin aging appearance. Purba et al [23] assessed dietary intake using a semi-quantitative Food Frequency Questionnaire (FFQ) and examined skin wrinkling via cutaneous microscopy and concluded that higher intakes of vegetables, fruit, olive oil and legumes may cause less skin wrinkling. Cosgrove et al. [22] examined nutrient intake via 24 hour recalls and clinical examinations of the skin finding that higher intakes of vitamin C and linoleic acid were associated with a lower likelihood of skin wrinkling, dryness and skin atrophy. Comparisons across these two studies were difficult due to demographic and methodological differences.

Body Image

One study [24] examined compliance to dietary guidelines and found that those who were in the highest tertile of a measure of compliance to American Dietary guidelines were more likely to have a positive body image.

3.4 Effectiveness of dietary interventions on appearance

Study characteristics, critical appraisal and results of included experimental studies are summarized in Tables 3, 4, and 5 respectively. The total number of participants across the 17 RCTs and one pre-post study was 997, of which at least 82% were females (13% unclear). The mean number of participants across all studies was 56 (Range 10 to 127). The age range of participants was 18 to 77 years, with one study not reporting the age of participants. The duration of studies ranged from seven days to a two-year intervention [25]. Fourteen interventions ranged from 8 to 14 weeks, two less than 8 weeks, two were 24 weeks [26, 27] and one two-years [25]. Only one study followed up participants after the end of the intervention which was an initial 6-week intervention with a further 6-weeks follow-up [28]. Retention rates varied from 64 to 100 % at post-intervention, the majority (16 of 18) of interventions had a retention rate of over 80%.

Studies were appraised for methodological quality with 14 assessed as being of "positive" and the remaining four of "neutral" quality. Twelve studies reported blinding. The source of funding was not stated in six studies. The majority of the studies (n=16) had comparable study groups, used appropriate statistics and measured outcomes in a valid and reliable method. Ten studies (55%) did not consider or mention potential limitations in their study.

Thirteen studies had two intervention arms (control/intervention) [25-27, 29-38], two had one arm [29] , one had three [39] and one had six intervention arms [28]. The majority of studies (15 out of 17) evaluated the effect of various dietary supplements with several active

ingredients. Polyphenols [27, 39], Omega 3 fatty acids [27, 32, 39], carotenoids [21], [32, 36], [27, 37] , vitamins E [27, 36, 37, 39] and C [36] [27, 37], Lactobacillus (La1) probiotics [29], green tea polyphenols [25, 30, 33], squalene [31], red ginseng [26] , and flavanol cocoa [34], whilst only one measured the effect derived from whole foods [28] which used foods high in beta-carotene.

Appearance outcomes included facial wrinkles (n=9), skin roughness and elasticity (n=7), skin color (n=6), cellulite (n=1), and body image (n=1). Ten studies used exclusively objective methods [21, 27-29, 31, 33, 34, 36, 37] to measure appearance outcomes whilst eight studies used a combination of objective and subjective evaluations (clinician and patient) [25, 26, 29, 30, 32, 35, 38, 39].

3.5 Effectiveness of interventions

Facial Wrinkles

Five of the nine studies that investigated the effect of dietary supplementation found significant improvements in facial wrinkles (periocular [26, 27, 31, 32, 38], forehead [27] and perioral[27] areas). These studies investigated various active ingredients and doses, including dietary supplements (n=3), [27, 32, 38] red ginseng root (n=1) [26] and squalene (n=1) [31] and measured facial wrinkles using skin replicas (impressions using silicon) or skin vision meters.

Three studies [25, 30, 33], which evaluated the effects of green tea supplementation; orally or topically, found no significant differences in facial wrinkling. Another study investigating the

impact of a high flavenol cocoa drink [34] found no significant changes in skin wrinkling after 12 weeks.

Skin Roughness and Elasticity

Of seven studies that examined intakes of various supplements on skin structure and texture, four found significant improvements in skin 'roughness' [33, 34, 37, 38] and three in skin elasticity [30, 33, 37]. Supplement intake from green tea and dietary supplements (with a variety of active ingredients) improved both skin elasticity and roughness whilst the intake of high flavonol cocoa improved skin roughness only [34].

Skin Color / Photoprotection

One study [36] examined the effects of two supplements containing various doses "high" (13mg/day of beta-carotene, 2mg lycopene) versus "low" (3mg/day of beta-carotene, 3mg lycopene) on the pigmentation of skin not exposed to UV light. Both supplements contained Vitamin C (30mg) and Vitamin E (5mg). Carotenodermia (yellowing of the skin) was only detectable with the higher dosage. A further study measured skin color change after eight weeks of beta-carotene (15mg/day) supplementation [21] and found significant increases in b* values in five skin regions [21].

One experimental study investigated the effects of following a diet high in carotenoids or use of beta-carotene supplements on skin color [28]. This was measured by visual examination of

the skin and fasting plasma carotenoids. The subjects who consumed the 30mg purified beta-carotene supplement daily for 42 days developed carotenodermia.

Three clinical trials [29] evaluated the effect of a dietary supplement containing lactobacillus (La1) and 7.2mg carotenoids (beta-carotene and lycopene) on UVR exposed skin, using three levels of exposure; extreme (UV-SSR), moderate (UV-DL) and natural summer sunlight. Trial one assessed early markers of UVR-induced skin damage using histology and immumohistochemistry [29]. In trial two, a chromameter was used to evaluate skin color changes, while in trial three both dermatologists and subjects completed assessment questionnaires on skin resistance to sun exposure [29]. There were significant increases in minimal erythema dose (MED) (threshold required to produce sunburn) after six weeks of dietary supplement (DS) intake ($p<0.05$). Skin color significantly increased after DS intake ($p<0.05$). In the third trial, dermatologists and subjects reported that dietary supplementation led to improvement in skin resistance to sun exposure [29]. Whilst MED isn't directly related to appearance a reduced sensitivity to sunburn is likely to have long-term ramifications for skin appearance.

Cellulite

One double-blinded study investigated the effects of two different dietary supplements on cellulite appearance [39]. Supplement one contained polyphenols, fatty acids, vitamin E, and extracts of ginkgo, ruscus, melilotus and Centella asiatica whilst supplement two had similar components except for omission of the fatty acids and vitamin E. Both clinical (completed by

physicians) and patient subjective evaluations indicated a significant improvement from the two products compared to the placebo group.

Body image

One study conducted by Lattimore et al [35] investigated perception of body image satisfaction after eating either a cereal or muffin breakfast for one week. Those in the cereal breakfast group were significantly more satisfied with their body ($p<0.001$) after eating breakfast than the muffin group.

3.6 Side effects/Adverse events

Adverse events or side effects from supplement or placebo consumption were reported in six RCTs [25-27, 30, 31, 37] including upper respiratory tract infection, loose stools or other minor gastrointestinal problems [25]. In one study, 55% of participants reported frequent incidence of loose stools (1-3 times daily) after consuming a high dose of squalene (27g/day) [31]. In another study by Segger et al [37] four out of the 58 participants reported gastric discomfort after taking an oral supplement which contained Pycnogenol (10 mg), vitamin C (30 mg), vitamin E (5 mg), biotin (75 mg), selenium (25 mg), zinc (7.5 mg), bio-marine complex (50 mg), horsetail and dietary carotenoids (34 mg) and did not continue with the study. A further study [25] reported side effects of loose stools and upper respiratory tract infection after consuming either two supplement tablets daily which included 250mg green tea polyphenols or from having the placebo capsules.

4. SUMMARY OF KEY FINDINGS

The current review identified 27 studies, nine of which were observational studies that examined the relationship between dietary intake and appearance, and 18 studies that evaluated the impact of a dietary intervention on appearance. Observational studies indicated that there was a significant association between various aspects of dietary intake and skin coloration and skin aging. The majority (n=15) of the dietary intervention studies were of positive methodological quality and found significant improvements in at least one actual or perceived appearance-related outcome following dietary intervention predominantly from supplement intake (n=15) or actual foodstuffs (n=1), with facial wrinkling, skin elasticity, roughness and skin color being the outcomes most commonly evaluated and reported.

4.1 Associations between dietary intake and appearance

Two cross-sectional studies [20, 21] reported significant associations between skin yellowness and fruit and vegetable intake. They also showed that changes in skin yellowness caused by modest improvements in fruit and vegetable intake are perceived to improve the appearance of health and attractiveness in Caucasians. However, the studies used a self-reported validated questionnaire to determine fruit and vegetable intake, which is based on an estimate of participants' intake rather than participants' actual intake. In addition, the sample sizes in the studies were moderate (range n=35 to 82) which could affect the generalizability of the results. The included participants were primarily Caucasian, further limiting external validity.

Two studies [22, 23] found an inverse association between higher dietary intakes of fruits and vegetables (which were self reported) and skin aging appearance, independent of factors known to affect skin aging such as smoking, age, sun exposure and race. However, these results may now be outdated as the data collected for one of the studies [22] was between 1971 to 1975 and changes in population level dietary patterns, sun exposure and UV radiation may have since changed.

All case studies reported change in skin color after consuming carotenoid rich foods and supplements containing beta-carotene. However, the amounts consumed (which was self-reported) from both foods and supplementation was largely outside the range of usual consumption, in particular, supplement intakes were 50 times above the normal daily intake of 87µg/dl for beta carotene [19]. Once consumption ceased from both the food and supplements, the skin returned to its normal color within a time frame of six weeks to six months. This was also confirmed by reduced plasma concentrations of lycopene [16] or carotene [18].

Based on the nine observational studies there is some evidence to support that there is a relationship between dietary intake and appearance. However, the numbers of studies are limited and each study has used different methodologies to assess appearance outcomes and dietary intakes. In addition as the majority of the observational studies were cross-sectional, temporality of associations are unable to be determined. Cross-sectional studies however can be informative for future longitudinal studies examining relationships between dietary intake and appearance.

4.2 Effectiveness of interventions

Almost all intervention studies (n=14) evaluated the effects of a dietary supplement on skin appearance in the context of skin aging or UV damage. It is not surprising that many of the retrieved studies focus on skin as this organ plays a major role in physical appearance, with its functioning and attractiveness known to be dependent on nutrition, particularly the intake of antioxidant vitamins, minerals and essential fatty acids [40].

Despite the lack of homogeneity across the studies in terms of the types of supplements used (individual supplements or complex mixtures), the majority were shown to have beneficial impacts on skin health and appearance in both the short and long term. Overall, we can conclude that supplements are effective in optimizing appearance of skin aging and protection against UV damage. However**,** as the interventions assessed here did not report follow-up results and varied in sample size, study duration and appearance-related outcomes it is not possible to determine the optimum dosage or specific active ingredients required to improve skin health and appearance.

Only one experimental study examined the effects of dietary intake of foods containing carotenoids on skin color and found that the participants consuming foods high in carotenoids did not develop carotenodermia and had lower plasma total carotenoid levels compared to those who consumed beta-carotene supplements. However, this was conducted over 25 years ago [28] and was a small sample of males. Therefore we cannot determine the actual impact of whole food intake on appearance. Further studies are needed to evaluate the effectiveness of food on appearance.

4.3 Study Quality

The overall quality of the included studies was moderate. Twelve of the RCT's were of moderate quality, four were classified as weak and there was only one strong quality RCT that met all criteria**.** Risk of bias was reasonably low in most studies, with the majority receiving a 'positive' classification. However, approximately half of the studies did not report their funding source, making it difficult to ascertain potential bias secondary to this. The studies that did report funding (n=8) were supported by skin, beauty, food or supplement corporations and this could be seen as a conflict of interest potentially affecting reporting bias. Two studies [25, 30] that examined the effects of green tea extracts or oral green tea on photo-aging of skin were funded by a company that produces anti-aging products. However, there were no significant improvements in the long-term skin status reported. Fourteen of the RCT's did not report handling of participant withdrawals. The clinical assessments and histologic grading of participants' skin conditions in a number of studies were conducted by qualified dermatologists who were blinded to treatment allocation therefore reducing risk of bias of the outcome assessments.

The retention rate for most of the experimental studies was quite high, with the majority reporting retention rates greater than 80%, which could be explained by the short duration of the studies, participant blinding, and the low participant burden. However, over half of the studies (8 of the 15) required participants to attend measurement sessions from three to six times throughout the study, so it is surprising that the retention rate was high in these studies, although the actual measurements were mostly non-invasive. Interestingly none of the 15 studies reported reimbursement for costs associated with travel.

The majority of studies (n=17) were conducted in female adults only. Thirteen of these studies specifically recruited female participants, therefore making the external validity of the studies uncertain and results may not be applicable to the general population, particularly for males. Hence, further research in more diverse population groups, including males is warranted to confirm the relationship between appearance and diet.

4.4 Side Effects

Less than half of the studies that were supplement based reported whether there were any side effects following consumption of oral supplements, making it difficult to determine whether there were in fact no side effects or side effects were not monitored within the studies. Hence, statements about safety cannot be made. Only one study [31] that reported positive results for skin aging concluded that the side effects of taking the supplement outweighed the beneficial results, suggesting further study was needed to evaluate outcomes using a smaller dosage.

This review has some limitations. Some recent or unpublished studies may have been missed as may have those published in languages other than English. However, a predefined protocol was utilized and a comprehensive search strategy employed across several databases along with a reference list search to identify the key studies in this area. In addition two independent reviewers were used for study inclusion, data extraction and quality appraisal in order to increase objectivity.

5. GAPS IN KNOWLEDGE AND FUTURE RESEARCH

This review has demonstrated that there is currently insufficient evidence to determine the association between actual food intake or dietary patterns and appearance only one study has examined this relationship. There is some evidence to suggest that supplements may contribute to improving appearance in particular with skin aging and UV damage, but these studies were heterogeneous in study design, appearance-related outcomes, supplement regimens and the majority of them were conducted in females only. Further studies are needed in representative populations that examine actual food consumption on appearance, using validated tools in a well-designed high quality RCT. In addition, higher quality studies are required that examine the effects of supplements on appearance. There is also a need for high quality large observational studies such as prospective cohort studies to examine the relationship between food intake and appearance and therefore, generate hypotheses for future RCTs.

Furthermore, as future research is undertaken systematic reviews may be conducted that focus only on high quality RCTs to determine the effectiveness of dietary interventions on perceived or actual appearance.

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Table 1: Design Characteristics of Case studies included in the review

Author Year. Title	Setting	Study Participants	Exposure	Signs and Symptoms Diagnosis	Results after follow-up
Caroselli et al 2008 [16]	Rome, Italy	68 year old Caucasian female.	Consumption of excessive amounts (~1kg/day) of Kaki fruit for 12 months.	Red-orange tinged skin of palms and soles of feet. Diagnosed with lycopenaemia.	Stop ingesting the Kaki diet and condition gradually subsided and serum lycopene levels returned to normal.
Nishimura et al 1998 [17]	Yokohama City University Hospital, Japan	22 year old female, Japanese, NIDDM (medications: glibenclamide), BMI 16.4, 14-17kg weight loss in previous 3 years on a 'diet'.	Patient reported eating average of 50 (range 10-60) sheets of Nori daily (50mg β-carotene) over a period of 5 months.	Orange-yellow color changes in skin, notable palms, soles and face (Sclera were normal). Pigmentation began 3 months prior to presentation.	Skin color returned almost to normal six months after ceasing Nori ingestion.
Takita et al 2006 [19]	Japan	66 year old female.	Ingested 6 x daily nutrient supplements (contained carotene) for 3 months, equivalent of 4410ug/dl.	Presented with yellow-orange discoloration of the skin and palms, diagnosed with carotenemia.	Stop ingesting supplements and condition gradually subsided.
Vakil et al 1985 [18]	Clinical setting (country NR)	32 year old female, Greek, BMI = 26.5 kg/m^2 (overweight).	Voluntary consumption of up to 2kg raw carrot and 0.5kg tomato per day for several months. Additionally consumed a diet rich in green vegetables, salads and fruit. Consumption was driven by a weight loss motive.	Yellow-orange discoloration on hands, soles of feet and nasolabial folds.	6 weeks reduced intake, skin color returned to normal.

Abbreviations: NR, not reported; BMI, body mass index; kg, kilograms; ug microgram;

Table 2: Design Characteristics of Cross-Sectional and Cohort studies included in the review

Author	Study Design	Objectives/Hypotheses	Setting	Duration	Sample Size	Participant Characteristics	Exclusion	Measures	Results
Whitehead et al 2012 **[20]**	Prospective Cohort	Investigate the effect of fruit and vegetables on skin color over a six week period.	University of St Andrews, Scotland	6 weeks	n=35	Male n=14, female n= 21. Mean age: 20.74 y ears, range: 18-25 years. Caucasian (n=34).	Recent sunbathing, use of self-tanning products, solariums or facial makeup, or skin lightness > 2sd from mean.	Fruit and vegetable intake: 63 item FFQ baseline, 3, 6 weeks. Skin color and reflectance, Konica Minolta Spectrophotometer, CIE L*a*b values, spectral wave lengths between 400 and 540 nm seven body sites.	Skin lightness decreased, redness and yellowness changes were significantly associated with increase fruit & vegetable intake. Overall skin reflectance change was significantly correlated with the absorption spectra of beta carotene and lycopene.
Stephen et al 2011 [21]	Cross-sectional	Compare skin color to natural dietary consumption of carotenoids.	Scotland	NA	n=82	Male n= 34, female n= 48. Age range: 18-26 years. Caucasian.	None	Fruit and vegetable intake: FFQ. Skin color: using a Spectrophotometer (CIELab) on four location sites. Reflectance spectra.	Higher daily intakes of fruit and vegetables and β-carotene had yellower skin (higher b* values) at multiple body sites ($r=0.25$ $p<0.026$).

Table 2: Design Characteristics of Cross-Sectional and Cohort studies included in the review

Author	Study Design	Objectives/Hypotheses	Setting	Duration	Sample Size	Participant Characteristics	Exclusion	Measures	Results
Cosgrove et al 2007 [22]	Cross-sectional	To examine the relationships between nutrient intakes and skin aging appearance.	Data sourced from NHANES I survey conducted in the United States 1971-1974.	NA	n=4025	Women aged 40 years or over who took part in the NHANES I (n=4025). (Mean ± SD) Age: 58.1±11.2 years. BMI 26.4±5.6 kg/m^2. White: 82.2%.	Exclusion: unsatisfactory/incomplete data from dermatologic examination and 24 hour dietary recall.	Nutrient intake (sourced from 24h recall) expressed as daily totals. Skin texture and color by clinical dermatological examination Skin ageing defined by 3 independent determinants (wrinkled appearance, senile dryness and skin atrophy).	Higher vitamin C lower likelihood of wrinkled appearance (0R) 0.89, senile dryness (0.93). Higher linoleic acid intakes - lower likelihood of senile dryness and skin atrophy. Increase in fat and CHO consumption increases the likelihood of wrinkled appearance (OR: 1.28, 1.36).
Purba et al 2001 [23]	Cross-sectional	To determine whether food and nutrient intakes are correlated with skin wrinkling in a sun exposed site.	Australia Greece Sweden	NA	n=453	Male n=247, female n= 206. Age range: 70 -104 years. n=177 Greek born living in Melbourne. n=69 Greek living in Greece. n=48 Anglo-Celtic Australian. n=159 Swedish living in Sweden.	None	Validated semi FFQ with cultural-specific foods and dishes. Grouped into minor (55, 77, 43) and major food groups (10). Skin wrinkling: using cutaneous microtopic method to assess actinic damage.	Swedish had the least skin wrinkling in a sun-exposed site, less actinic skin damage with higher intake of vegetables (r=-0.249, p<0.0001) fish, olive oil and legumes. High intakes of vegetables, legumes and olive oil protective against cutaneous actinic damage.

Table 2: Design Characteristics of Cross-Sectional and Cohort studies included in the review

Author	Study Design	Objectives/Hypotheses	Setting	Duration	Sample Size	Participant Characteristics	Exclusion	Measures	Results
George et al 2005 [24]	Cross-sectional	To evaluate compliance with dietary guidelines in late postpartum in low income women.	USA	NA	n=146	n= 146 female. Inclusion: 18 years or older, white, African, American or Hispanic, parity ≤ 3, read, write and speak English, telephone access, family incomes ≤ 185% of poverty guidelines.	None	Dietary intake: validated semi-quantitative 195 FFQ. Dietary guidelines index compliance score obtained from FFQs, BMI at 1 year and physical activity. Body dissatisfaction: Body cathexis scale: 30 item validated instrument that measures.	Greater compliance with dietary guidelines was associated with lower perceived barriers to weight loss and less body image ($p<0.05$).

Abbreviations: BMI, body mass index; NA, not applicable, mo, months; FFQ, Food frequency questionnaire;

Table 3. Design Characteristics of Experimental studies included in the review

Author	Study Design	Setting	Duration	Age (years)	BMI (kg/m2) Weight (kg)	Sample Size	Ethnicity	Smoking	Inclusion	Exclusion	Retention	Follow up
Bacci et al 2003 [39]	Double Blinded RCT	Italy	47 days	Mean: 31.6 Range: 18-45	NR	n=127 (gender NR)	NR	NR	Cellulite ≥ 2 years.	BMI>30kg/m², adipose cellulite, menopause/pre-menopause, sagging skin.	87.60%	Nil
Bouilly-Gauthier et al 2010 [29]	Clinical Trial 1	France	14 weeks	Mean ± SD: 31± 3	NR	n=16 Females n=16 (100%)	NR	NR	Healthy women, abstain from dairy products during study period.	Pregnant, breastfeeding, supplement/ vitamin intake and particular diet.	100%	Nil
Bouilly-Gauthier et al 2010 [29]	Clinical Trial 2 Double Blinded RCT	France	68 days	Mean ± SD: 34 ± 7 (DS Group) Mean ± SD: 35 ± 7 (Placebo group)	NR	n=43 Females n=43 (100%)	NR	NR	Healthy women, abstain from dairy products during study period.	Pregnant, breastfeeding, supplement/ vitamin intake and particular diet.	100%	Nil
Bouilly-Gauthier et al 2010 [29]	Clinical Trial 3 Open study	France	6-8 weeks	Mean ± SD: 42 ± 12	NR	n=80 Females n=80 (100%)	NR	NR	Nil, not to change habits of sunbathing or sunscreen use.	Pregnant, breastfeeding, supplement/ vitamin intake, hx of skin cancer.	100%	Nil
Chiu et al 2005 [30]	Double Blinded Placebo RCT pilot study	USA	8 weeks	NR	NR	n=37 Females n=37 (100%)	NR	NR	Moderate photaging Fitzpatrick skin phototypes I – III.	Steroid or retinoid use, change in HRT < 6mo.	92.50%	Nil
Cho et al 2009 [31]	RCT	Korea	90 days	Mean: 57.8 Range: 50-72	Mean wt: 56.4 Range: 44-70	n=37 Females n=37 (100%)	NR	NR	NR	Corticosteroid or retinoid use 2 weeks prior study.	92.50%	Nil
Cho et al 2009 [26]	Double Blinded Placebo RCT	Korea	24 weeks	Mean: 51.9 Range: 40 - 70	Mean: wt: 57.0 Range: 43-81	n=82 Females n=82 (100%)	NR	NR	NR	Age <40y, pregnancy, lactation, infectious skin disorder on face, atopic dermatitis, photoallergic or photosensitive skin, renal or chronic diseases.	95.30%	Nil

Abbreviations: RCT, Randomized Control Trial;NR, not reported; wt, weight; BMI, body mass index; hx, history; ds, dietary supplement; NA, not applicable, mo, months; y, year;

Table 3. Design Characteristics of Experimental studies included in the review

Author	Study Design	Setting	Duration	Age (years)	BMI (kg/m2) Weight (kg)	Sample Size	Ethnicity	Smoking	Inclusion	Exclusion	Retention	Follow up
Dayan et al 2011 [32]	Double Blinded Placebo RCT	USA	270 days	Mean ± SD: 52 ± 12 Range: 30-77	NR	n=76 Female n= 61 (80%) Males n=15 (20%)	Caucasian (67%), African American (16%), Hispanic (13%), Asian-American (4%)	NR	NR	Chronic skin disease, tobacco smoker, vitamin supplement use within 30 days.	64%	Nil
Heinrichet al 2006 [34]	Double Blinded Placebo RCT	Germany	12 weeks	Range: 18-56	NR	n=24 Female n= 24 (100%)	NR	NR	Fitzpatrick skin phototypes II	Pregnant, breastfeeding, smokers, medication use sunbathing/ sunbed use.	100%	Nil
Heinrich et al 2011 [33]	Double Blinded Placebo RCT	Germany	12 weeks	Range: 40-65	BMI: 18-25 kg/m^2	n=60 Female n=60 (100%)	NR	NR	Fitzpatrick skin phototypes II	Pregnant, breastfeeding, smokers, medications, sunbathing/ sunbed use. Vitamin/ supplements use.	100%	Nil
Janjua et al 2009 [25]	Double Blinded RCT	USA	2 years	Range: 25-75	Healthy	n=34 Female n=34 (100%)	NR	NR	Moderate photoaging scale II or III) Fitzpatrick skin phototypes I to III	Systemic retinoid use 6 weeks prior, active facial dermatologic conditions, hx facial cosmetic procedure.	60.70%	Nil

Abbreviations: RCT, Randomized Control Trial;NR, not reported; wt, weight; BMI, body mass index; hx, history; ds, dietary supplement; NA, not applicable, mo, months; y, year;

Table 3. Design Characteristics of Experimental studies included in the review

Author	Study Design	Setting	Duration	Age (years)	BMI (kg/m2) Weight (kg)	Sample Size	Ethnicity	Smoking	Inclusion	Exclusion	Retention	Follow up
Lattimore et al 2010 [35]	RCT	North West England	7 days	Range: 20-40	BMI Range: 19.5-29.5kg/m^2	n=123 Female n=123 (100%)	NR	NR	NR	Food allergies/ gluten intolerance, current/ past hx eating /mental health disorders, pregnant, diabetic, anti-depressants or wt loss medication.	95.30%	Nil
Micozzi et al 1988 [28]	RCT	USA	12 weeks	Range: 20-45	Wt range: 64.1- 92.7	n=30 Male n=30 (100%)	NR	NR	No hx of chronic disease, non-smokers, within 10% of IBW, no unusual dietary patterns	None	100%	6 weeks
Postaire et al 1997 [36]	Double Blinded RCT	Germany	8 weeks pre/post	Mean ± SD: 32.4±7.5 Range: 22-46	67.17±11.3	n=20 Female n=11 (55%) Male n=9 (45%)	Caucasian	NR	Healthy, skin phototype II	ds or drug study within previous 3 months, malabsorption problems, liver disease, obese, smokers, >30g alcohol/day 15 days prior, ds use.	100%	Nil
Segger et al 2004 [37]	Double Blinded RCT	Germany	12 weeks	Range: 45-75	NR	n=58 Female n=58 (100%)	NR	NR	Fitzpatrick skin, phototypes I-IV, Free of skin disease, warts, scabs little /no hair, no tattoos.	Chronic disease, pregnancy, breastfeeding.	93.50%	Nil

Abbreviations: RCT, Randomized Control Trial;NR, not reported; wt, weight; BMI, body mass index; hx, history; ds, dietary supplement; NA, not applicable, mo, months; y, year;

Table 3. Design Characteristics of Experimental studies included in the review

Author	Study Design	Setting	Duration	Age (years)	BMI (kg/m2) Weight (kg)	Sample Size	Ethnicity	Smoking	Inclusion	Exclusion	Retention	Follow up
Skovgaard et al 2006 [27]	Double blinded Placebo RCT	USA	6 months	Range: 45-65	NR	n=80 Female n=80 (100%)	NR	NR	1-5y post-menopause Fitzpatrick skin type II-III, BMI 20-30kg/m2, <10 cigarettes/day avoided excessive sun/sun bed exposure	Skin/ mental or uncontrolled metabolic disease, hx: breast/ ovarian cancer, gastro-intestinal disease, impaired circulation, allergy or sensitivity to seafood or soy, prescription drug use for improving skin appearance, ds use of oral vitamin/ nutritional supplement equal to >1 multivitamin.	80%	Nil
Stephen et al 2011 [21]	Pre and post	Scotland	8 weeks	Range: 19-22	NR	n=10 Male n= 2, Female n= 8	NR	NR	NR	NR	100%	Nil

Abbreviations: RCT, Randomized Control Trial;NR, not reported; wt, weight; BMI, body mass index; hx, history; ds, dietary supplement; NA, not applicable, mo, months; y, year;

Table 3. Design Characteristics of Experimental studies included in the review

Author	Study Design	Setting	Duration	Age (years)	BMI (kg/m2) Weight (kg)	Sample Size	Ethnicity	Smoking	Inclusion	Exclusion	Retention	Follow up
Udompataikul 2009 [38]	Double Blinded placebo RCT	Thailand	12 weeks	Range: 35-60	NR	n=60 Female n=60 (100%)	Thai	NR	No daily sun exposure, non-smoker, no hx of allergy to seafood, coenzyme Q10, vitamin E, green tea, grape seed extract, French maritime pine bark extract, β-carotene, selenium or zinc.	Received anti-aging interventions >3 months prior to consuming or antiageing compounds (e.g. vitamin E or C) within 3mo of study, oral retinoid <6mo pre study, or applied topical AHA, BHA, retinoid, retinol, vitamin E, C or any other compounds that may interfere <3mo pre study, pregnant or lactating.	100%	Nil

Abbreviations: RCT, Randomized Control Trial;NR, not reported; wt, weight; BMI, body mass index; hx, history; ds, dietary supplement; NA, not applicable, mo, months; y, year;

Table 4: Primary Outcomes measures and results of Experimental studies included in the review

Author	Research question/ Hypothesis	Intervention	Outcome and types of measures	Results	Significance difference between groups or changes in outcomes Y/N Side effects
Bacci et al 2003 [39]	Evaluate the effect of two different dietary supplement/formulae on cellulite.	Group A: supplement containing polyphenols (bioflavonoids), fatty acids (EPA, DHA, γ-linoleic acid), vitamin E, ginkgo biloba, ruscus, melilotus and centella. Group B: placebo containing inert substances (natural fibers and soya oil). Group C: cellulase Gold supplement containing polyphenols (bioflavonoids), Recaptacell, ginkgo biloba, ruscus, melilotus, centella and fucus.	Cellulite improvement: Clinical (Score 2 to 8) and self-assessment (scale 0-10) questionnaires.	Higher scores given by treating physicians in for clinical and cosmetic appearance of participants post intervention for groups A and C ($p<0.001$). Overall improved subject improvement in groups A & C ($p<0.001$).	Y between groups Side effects: NR
Bouilly-Gauthier et al 2010 [29]	To assess the effects of dietary supplements containing La1 and nutritional doses of carotenoids on early UV Induced skin damage.	CT1: 18 day exposure to minimal erythema dose (0.75 MED) of UV daylight (UVA/UVB ration = 24) pre and post receiving supplement. Dietary supplement contained $5x10^8$ La1 (probiotic) and 7.2mg carotenoids (β-carotene & lycopene). Supplements were consumed daily for 6 weeks pre-UVR exposure.	Cell skin density skin condition: Biopsy sample taken from exposed and unexposed buttock areas before and after supplementation. Melanin: Fontanna masson stain used to revealed intraepidermal melanin.	After supplementation the melanin density was significantly lower $p<0.05$.	Y change in outcome Side effects: NR

Table 4: Primary Outcomes measures and results of Experimental studies included in the review

Author	Research question/ Hypothesis	Intervention	Outcome and types of measures	Results	Significance difference between groups or changes in outcomes Y/N Side effects
Bouilly-Gauthier et al 2010 [29]	To assess the effects of dietary supplements containing La1 and nutritional doses of carotenoids on early UV Induced skin damage.	CT2: 4 day exposure to 0.9 MED UV-SSR (UVA/UVB ratio=10) and 10 day skin color evaluation pre and post dietary Dietary supplement contained $5x10^8$ La1 (probiotic) and 7.2mg carotenoids (β-carotene & lycopene). Placebo: maltodextrin. Supplements were consumed daily for 6 weeks pre-UVR exposure.	Skin color: Minolta Chromameter before and after supplementation. MED: Clinical evaluation and Chromameter.	Increase in MED (+19%, $p<0.05$) after DS intake while no change in placebo. Clinical determination (+20 % $p<0.05$). Color difference Δ E* - an increase after DS intake but no change for placebo ($p<0.05$).	Y between groups Side effects: NR
Bouilly-Gauthier et al 2010 [29]	To assess the effects of dietary supplements containing La1 and nutritional doses of carotenoids on early UV Induced skin damage.	CT3: natural sunlight exposure during summer holidays (ax 3-4wk pre and post-holiday). Dietary supplement contained $5x10^8$ La1 (probiotic) and 7.2mg car0tenoids (β-carotene & lycopene). Supplements consumed daily for 3-4 weeks pre-UVR exposure.	Skin resistance to sun exposure: Questionnaires on skin exposure to sun exposure one by subject & the other by dermatologist.	Dermatologists reported DS prevented sunburn, sun intolerances and appearance of sunspots in participants that usually experience these phenomena. Participants noticed improved skin color (intensity, evenness) and better skin condition.	Y change in outcomes Side effects: NR

Table 4: Primary Outcomes measures and results of Experimental studies included in the review

Author	Research question/ Hypothesis	Intervention	Outcome and types of measures	Results	Significance difference between groups or changes in outcomes Y/N Side effects
Chiu et al 2005 [30]	Investigate oral and topical green tea supplementation and their possible effects on aging skin.	Green tea treatment apply 10% green tea extract cream 2 x daily to face & arms, 300mg green tea oral sup 2 x daily. Placebo group: placebo cream 2 x daily to face & arms, placebo oral sup 2 x daily.	Facial skin (wrinkles, roughness, dryness, overall), clinical assessment and histologic grading of skin biopsies. Self-assessment on facial skin (scale 0 to 5).	No significant difference clinical grading between groups. Histologic grading of skin biopsies showed significant improvements in elastic tissues in treatment group ($p < 0.05$). Significant differences between groups, placebo group rating have less dry skin ($p<0.01$) and superior overall appearance ($p<0.05$).	N between groups and clinical grading Y between groups histologic grading s Side effects: skin irritation from topical
Cho et al 2008 [31]	Investigate if squalene supplementation improves signs of photo ageing in human skin.	High dose squalene: 27g/day Low dose: 13.5g/day	Facial wrinkles, measured by Skin replica and Visionmeter. Facial erythema and pigmentation, measured by Derma Spectrometer.	Facial wrinkles decreased in both groups, however in high dose group all R values significantly decreased after 90 days supplementation ($p<0.05$). Melanin indices increased and erythema indices decreased from the cheek area in both groups post squalene supplementation ($p<0.05$)	Y between groups Side effects: observed loose stool/diarrhoea 35%, 55% participants low and high dose respectively, High blood cholesterol for 3 participants

Table 4: Primary Outcomes measures and results of Experimental studies included in the review

Author	Research question/ Hypothesis	Intervention	Outcome and types of measures	Results	Significance difference between groups or changes in outcomes Y/N Side effects
Cho et al 2009 [26]	Investigate whether repeat oral administration of red ginseng extracts and herbal mixtures can reduce wrinkly formation.	Supplement: 3g/day (10 capsules) of KTNG0345 (45.3% Korean red gingseng extract & 54.6% powder extract of torilus fructus & corni fructus). Placebo: 226.5mg dextrin and 70mg caramel color. FFQ 25 specific foods, baseline, 12 and 24 weeks.	Facial wrinkles (skin replicas and skin visiometer). Elasticity, measured by Cutometer. Facial erythema and pigmentation, measured by DermaSpectrometer on face cheek. Clinical assessment of facial wrinkles, elasticity and pigmentation from both investigators and subjects (scale).	Facial wrinkles R1 and R5 values significantly improved after 12 (14.7%, 19.0% respectively) and 24 weeks (14.1%, 23.4%). No significant differences were found between groups for elasticity and facial pigmentations. No significant difference in responses on improvements (as per subjects and dermatologists at 12/24 weeks).	Y between groups N between groups Side effects: gastric discomfort no adverse events in groups.

Table 4: Primary Outcomes measures and results of Experimental studies included in the review

Author	Research question/ Hypothesis	Intervention	Outcome and types of measures	Results	Significance difference between groups or changes in outcomes Y/N Side effects
Dayan et al 2011 [32]	To determine the effect of Skin Health Experimental Product (SHEP) on skin health.	Active Treatment: SHEP supplement food-based mixture of ascorbic acid, omega-3 fatty acids, mixed carotenoids, zinc rice chelate, luetin, pyridoxine, pantothenate, niacin, choline and coenzyme Q10. Control: identical appearing capsule.	Skin Profilometry: Major and minor skin lines measured by topographical analysis using silicon profilometry of the periorbital skin (SkinReplica) obtained at day 60, 90, 180 and 270. Skin Carotenoid concentration: measured by Resonance Raman Spectroscopy at 270 days of subjects stratum corneum obtained from palm and four interdigital webs of dominant hand. Self-image: Global Aesthetic Improvement Scale (GAIS) performed at 60, 90, 180 and 270 days.	Significant reduction in fine lines (p=0.0194) for active treatment group. Carotenoids were detectable at 2 peaks which correspond to the 2 strongest found in the skin (1159 and 1524 cm-1) Site 1 to Site 5. All significant except site 3(third and ring finger) and 5 (palm). More subjects in the placebo group responded "worse" to facial changes post intervention (p=0.019). Active treatment subjects more likely to experience subjective improvement to facial comparisons post intervention (p=0.04).	Y between groups Side effects: NR

Table 4: Primary Outcomes measures and results of Experimental studies included in the review

Author	Research question/ Hypothesis	Intervention	Outcome and types of measures	Results	Significance difference between groups or changes in outcomes Y/N Side effects
Heinrich et al 2006 [34]	To investigate the effects of intake of product rich in cocoa flavanols on skin sensitivity toward UV exposure.	HF group (n=12): cocoa beverage -329mg of total cocoa flavonols (TCF). LF group (n=12): nutrient matched cocoa beverage -27mg of TCF. Consumed 1 x daily with morning meal for 12 weeks. Advised not to change dietary habits and no supps (vitamins/ polyphenols).	Sensitivity towards UV radiation (baseline, 6 12, skin color was measured before and 24hours after irradiation) by chromametry. Skin structure and texture measured with high-frequency ultrasound B-scan with 2-D-configuration. Skin hydration by chromametry.	a* values, significant ↓in HF group by 15 and 25%, no change in LF Group mod but significant ↑HF Group density and thickness of skin $p<0.05$. Moderate but significant ↑ HF Group density and thickness of skin $p<0.05$. Skin surface profiles evaluated by SEL method; roughness, scaling, smoothness and wrinkles: significant ↓in skin roughness and scaling for HF Group. Skin hydration significantly↑ in HF Group.	Y between groups Side effects: NR

Table 4: Primary Outcomes measures and results of Experimental studies included in the review

Author	Research question/ Hypothesis	Intervention	Outcome and types of measures	Results	Significance difference between groups or changes in outcomes Y/N Side effects
Heinrich et al 2011 [33]	To investigate the effects of repetitive intakes of a beverage enriched with green tea polyphenols on skin sensitivity toward UV exposure, skin structure and texture.	Green Tea group consumed 1L of green tea beverage each day (1402mg total tea catechins). Control group: ingested 1L of a constituent matched beverage with a replicate taste daily.	Sensitivity towards UV radiation (baseline, 6 12, skin color was measured before and 24hours after irradiation) by chromametry L*a*b values. Skin elasticity based on suction method using Cutometer SEM 474 on inner forearm. Skin structure and texture measured with high-frequency ultrasound B-scan with 2-D-configuration. Skin surface (photos) was characterised by roughness, scaling, volume and winkles.	a*values↓16-25% (6 wk. 12wk) in GT Group indicating improved photo protection ($p < 0.05$). Viscoelasticity ↓by 21% 12 wks for GT group ($p < 0.05$). Skin density ↑by 7.7% after 12 wks ($p < 0.05$). Wrinkles↓ by wk 12 $p<0.05$ ($p < 0.05$).	Y between groups Side effects: NR

Table 4: Primary Outcomes measures and results of Experimental studies included in the review

Author	Research question/ Hypothesis	Intervention	Outcome and types of measures	Results	Significance difference between groups or changes in outcomes Y/N Side effects
Janjua et al 2009 [25]	To evaluate the long term effects of oral green tea polyphenols on photo aging skin.	Green tea: one capsule 2 x daily (contained 250mg polyphenols). Placebo group: placebo capsule 2 x daily.	Sun exposed arm skin: by histological assessment of arm skin samples by blinded dermatologists. Facial skin: clinical assessment using digital left sided facial photographs (wrinkles, hyperpigmentation, pore size, roughness and overall assessment of solar damage) scaled by a blinded dermatologist.	No significant differences between groups at 24 mo Overall solar damage was reduced from baseline to 6 mo in green tea group (p=0.02). No significant differences in any time points for hyperpigmentation, poor size, roughness or wrinkling between groups.	N between groups Side effects: Adverse events upper respiratory tract infection (7 events in green tea group, 4 in placebo). Loose stools (5 in tea group, 3 in placebo)
Lattimore et al 2010 [35]	To investigate the effect of consuming isocaloric breakfasts appearing in different in calorie content on appetite, mood and body image satisfaction.	Muffin breakfast: 1 commercially produced chocolate chip muffin and a pure apple juice for 7 days. Cereal breakfast: 392kcal with portion of breakfast cereal, semi-skimmed milk, whole meal bread toasted with low fat spread, and pure apple juice for 7 days.	Appetite, mood, body-image satisfaction, by a diary using Visual Analogue scale (VAS).	Cereal breakfast gave participants higher body and weight satisfaction than the muffin breakfast.	Y between groups Side effects: NR

Table 4: Primary Outcomes measures and results of Experimental studies included in the review

Author	Research question/ Hypothesis	Intervention	Outcome and types of measures	Results	Significance difference between groups or changes in outcomes Y/N Side effects
Micozzi et al 1988 [28]	To evaluate the relation between plasma carotenoid levels and carotenodermia receiving supplementation for 42 days.	30mg carotenoid: 1. Purified β-carotene capsule 2. Carrots - 272g 12mg carotenoid: 3. Purified β-carotene capsule 4. Tomato Juice - 180g 6mg carotenoid: 5. Broccoli - 300g 6. Placebo - BHA, BHT and sodium benzoate capsule Strictly controlled diet (3000kcal with constant, low carotenoid content 0.5-1.6mg/day).	Carotendermia: blood carotenoids samples using HPLC. Plus physical examination of skin (zygomatic prominence, hands, elbows, knees and feet).	Group 1 (30mg supplement) was the only group to experience unequivocal carotenodermia with presences first noted day 25 of tx - 7d post supplementation, and remained yellow >14 days.	N between groups Side effects: NR
Postaire et al 1997 [36]	The role of antioxidant nutrient intakes on pigmentation of the skin without any UV exposure.	Supplement 1 (B13/L2): 2 capsules containing 5mg natural totopherol, 30mg ascorbic acid, 13mg β-carotene and 2mg lycopene. Supplement 2 (B3/L3): 2 capsules containing 5mg natural tocopherol, 30mg ascorbic acid, 3mg β-carotene, 3mg lycopene.	Skin color: Chromater CR200 for L*a*B* values. Melanin and carotene concentration, multiple reflection Spectrophotometry (Multiscan -OS10) at selective sites.	No significant influence on skin color in subjects consuming B3/L3 dosage. Only differences in subjects with B13/L2 dosage occurred with b-values on forehead (1.08) and inside of hand (2.27) as compared to baseline means (b-values represent yellow components of the skin). Increases in carotene concentration with B13/l2 group, melanin increases in both groups.	Y between groups and outcomes Side effects: NR

Table 4: Primary Outcomes measures and results of Experimental studies included in the review

Author	Research question/ Hypothesis	Intervention	Outcome and types of measures	Results	Significance difference between groups or changes in outcomes Y/N Side effects
Segger et al 2004 [37]	To investigate whether supplementation with Evelle, may improve skin roughness and elasticity in women aged 45 years > over.	Verum group: two Evelle tables 2 x day (Vit C, E carotenoids, Se, Zn, amino acids, blueberry extract and pycnogenol). Placebo group: placebo tables identical with none of the above ingredients 2 x daily.	Skin elasticity using Cutometer. Skin roughness: 3D Microtopography imaging system.	Skin elasticity significantly ↑by 9% after 6 weeks in the treatment group (p=0.0351). Roughness significantly↓ by 6% in the treatment group after 12 weeks (p=0.0157).	Y between groups Side effects: gastric discomfort from 4 subjects
Skovgaard et al 2006 [27]	To quantify the effects on skin in post-menopausal women with a novel dietary supplement.	Active treatment: supplement containing 350mg soy extract, 210mg biomarine complex (fish protein polysaccharides), 118.7mg ViTea, 27.5mg grape seed extract, 28.8mg tomato extract, 60mg vitamin C, 10mg vitamin E, 5mg zinc, and 100mg chamomile (in evening tablets only). Placebo: 1115mg maltodextrin, 266mg starch, 95.8mg burnt sugar, 30.4mg silicon dioxide, 11.4mg magnesium stearate and 0.76mg riboflavin.	Clinical grading of skin (0-9 scale) and photo evaluation of wrinkles. Skin denisty using DUBplus 20 of crows foot area. Skin elasticity Cutometer SEM 575.	Significant improvements on skin grading ($p<0.05$) compare to placebo for - wrinkles, hyperpigmentation, crepyness overall appearance (6mo) - decolletage crepyness (2, 3, 6mo) and overall appearance (3, 6mo) - hand crepyness (3, 6mo), mottled hyperpigmentation (3mo) Significant improvement on the face after 3 and 6 months from photo evaluation ($p<0.05$). Significant differences in skin density between groups at 6 months $p<0.05$. No significant difference for skin elasticity.	Y/N between groups Side effects: adverse event swollen tongue from one participant in active treatment group

Table 4: Primary Outcomes measures and results of Experimental studies included in the review

Author	Research question/ Hypothesis	Intervention	Outcome and types of measures	Results	Significance difference between groups or changes in outcomes Y/N Side effects
Stephen et al 2011 [21]	Establish carotenoid-skin color relationship in response to dietary supplementation with carotenoids.	Beta-carotene supplementation 15mg/day.	Skin color: using Spectrophotometer (CIE Lab values) in six location sites.	Significant increases of skin b*values in five of the six locations.	Y in outcome Side effects: NR
Udompataikul 2009 [38]	To evaluate the potential benefits of an oral nutraceutical on cutanoues ageing.	Active treatment group: nutraceutical containing coenzyme Q10, antioxidants (beta-carotene, D-alpha-tocopheryl-acetate, grape seed extract, green tea extract, selenium, zinc and GAGs). Placebo: identical capsules without active ingredients.	Skin ageing: assessed by 3 dermatologists at baseline, 4, 8 and 12 wks of tx evaluation using a Visiometer SV600. Patient Satisfaction Questionnaire of tx - decrease & homogeneity of skin color, reduction in pore size, skin roughness and wrinkles.	Statistically significant reductions occurred in the active treatment group at week 4 ($p = 0.001$), 8 ($p = 0.000$) and 12 ($p = 0.000$) [21.2% improvement in comparison to 1.7% in control] No significant difference in satisfaction regarding pigmentation change, however significant differences existed in the level of satisfaction on reduction of pore size, skin roughness and fine wrinkles.	Y/N between groups Side effects: NR

Abbreviations: Wks, Weeks; tx, treatment; mo, months; Y, yes; N, no; mg, milligrams; NR, not reported; ↑ increase ↓decrease

Table 5: Methodological quality of Included studies

Author	Study Design	1.Was the research question clearly stated?	2.Was the selection of study subjects/patients free from bias?	3.Were study groups comparable?	4.Was method of handling withdrawals described?	5.Was blinding used to prevent introduction of bias?	6. Were intervention/therapeutic regimens/exposure factor or procedure described in detail?	7.Were outcomes clearly defined and the measurements valid and reliable?	8.Was the statistical analysis appropriate for the study design and type of outcome indicators?	9.Were conclusions supported by results with biases and limitations taken into consideration?	10. Is bias due to study's funding or sponsorship unlikely?	Overall Quality *
Purba et al 2001 [23]	Cross-sectional	Y	Y	Y	N	N	Y	Y	Y	N	Y	P
Cosgrove et al 2007 [22]	Cross-sectional	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	P
Stephen et al 2011 [21]	Cross-sectional	Y	Y	Y	N	N	Y	Y	Y	N	Y	P
Whitehead et al 2012 [20]	Prospective Cohort	Y	Y	Y	N	N	Y	Y	Y	Y	Y	P
George et al 2005 [24]	Cross-sectional	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	P
Bacci et al 2003 [39]	Double Blinded RCT	Y	Y	Y	N	Y	Y	Y	N	N	Y	P
Bouilly-Gauthier et al 2010 [29]	Clinical Trial 1	Y	Y	Y	N	Y	Y	Y	Y	Y	N	P
Chiu et al 2005 [30]	Double Blinded Placebo RCT pilot study	Y	Y	Y	N	Y	Y	Y	Y	Y	N	P

Table 5: Methodological quality of Included studies

Author	Study Design	1.Was the research question clearly stated?	2.Was the selection of study subjects/patients free from bias?	3.Were study groups comparable?	4.Was method of handling withdrawals described?	5.Was blinding used to prevent introduction of bias?	6. Were intervention/therapeutic regimens/exposure factor or procedure described in detail?	7.Were outcomes clearly defined and the measurements valid and reliable?	8.Was the statistical analysis appropriate for the study design and type of outcome indicators?	9.Were conclusions supported by results with biases and limitations taken into consideration?	10. Is bias due to study's funding or sponsorship unlikely?	Overall Quality *
Cho et al 2008 [31]	RCT	Y	Y	Y	N	N	Y	Y	Y	Y	Y	P
Cho et al 2009 [26]	Double Blinded, Placebo RCT	Y	Y	Y	N	Y	Y	Y	Y	Y	N	P
Dayan et al 2011 [32]	Double Blinded Placebo RCT	Y	Y	Y	N	Y	Y	Y	Y	Y	N	P
Heinrichet al 2006 [34]	Double Blinded Placebo RCT	Y	Y	Y	N	Y	Y	Y	Y	N	N	P
Heinrich et al 2011 [33]	Double Blinded Placebo RCT	Y	Y	Y	N	Y	Y	Y	Y	N	N	P
Janjua et al 2009 [25]	Double Blinded RCT	Y	Y	Y	Y	Y	Y	Y	Y	N	N	P
Lattimore et al 2010 [35]	RCT	Y	Y	Y	N	N	Y	Y	Y	N	N	n
Micozzi et al 1988 [28]	RCT	Y	Y	N	N	N	Y	N	N	N	Y	n
Postaire et al 1997 [36]	Double Blinded RCT	Y	Y	Y	N	Y	N	N	N	N	Y	n
Segger et al 2004 [37]	Double Blinded RCT	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	P

Table 5: Methodological quality of Included studies

Author	Study Design	1.Was the research question clearly stated?	2.Was the selection of study subjects/patients free from bias?	3.Were study groups comparable?	4.Was method of handling withdrawals described?	5.Was blinding used to prevent introduction of bias?	6. Were intervention/therapeutic regimens/exposure factor or procedure described in detail?	7.Were outcomes clearly defined and the measurements valid and reliable?	8.Was the statistical analysis appropriate for the study design and type of outcome indicators?	9.Were conclusions supported by results with biases and limitations taken into consideration?	10. Is bias due to study's funding or sponsorship unlikely?	Overall Quality *
Skovgaard et al 2006 [27]	Double Blinded Placebo RCT	Y	Y	Y	N	Y	Y	Y	Y	N	Y	P
Stephen et all 2011 [21]	Pre –post study	Y	N	N	N	N/A	Y	Y	Y	N	Y	n
Udompataikul 2009 [38]	Double Blinded Placebo RCT	Y	Y	Y	N	Y	Y	Y	Y	N	Y	P

Abbreviations: Y, Yes; N, No; P, Positive; n, neutral

* Studies were appraised as 'positive' if they answered "yes" (including criteria 2,3,6,7) and at least one additional "Yes"

Figure 1: Flow diagram of studies included in review

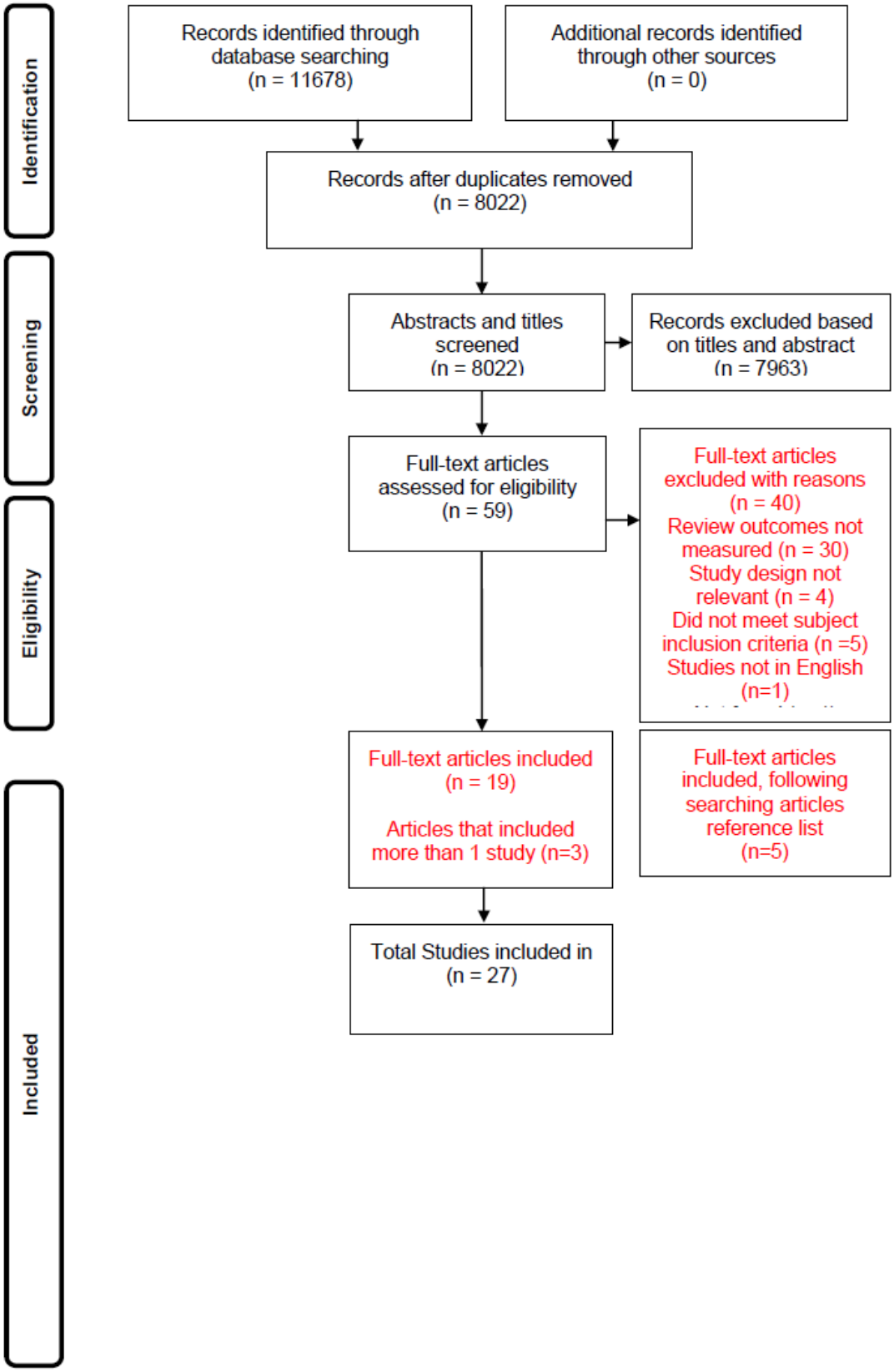

Figure 1

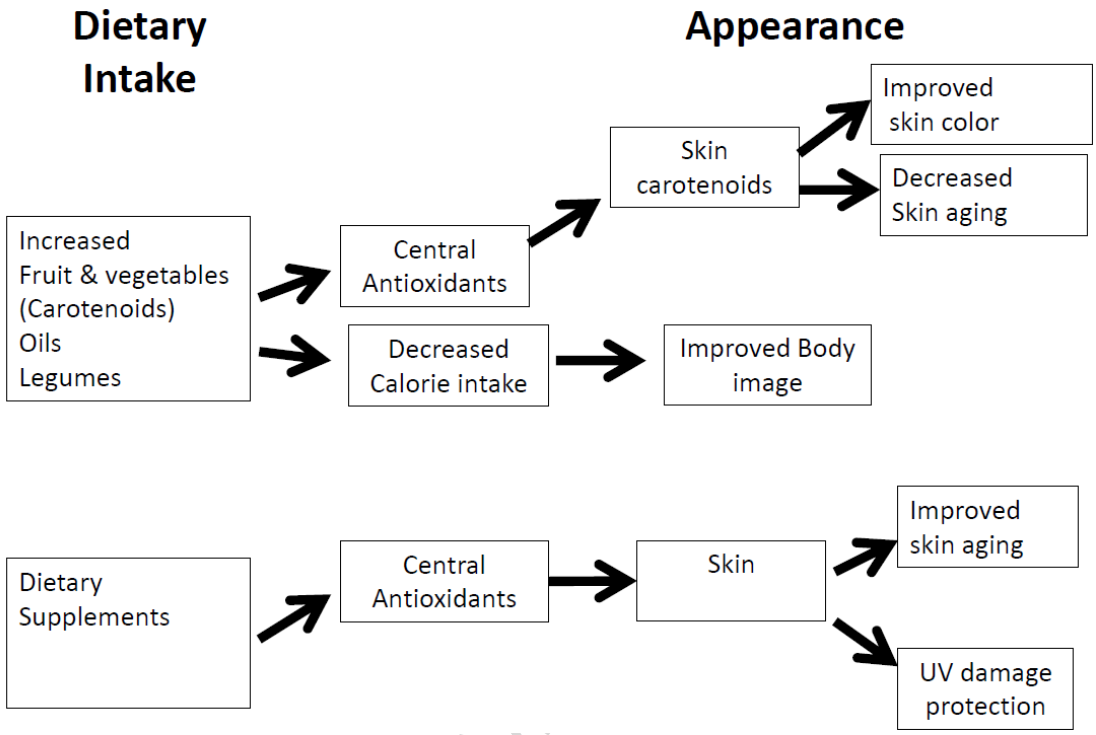

Figure 2