Original Research

Skin Wrinkling: Can Food Make a Difference?

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Key words: food intake, nutrients, Caucasian elderly, actinic skin wrinkling, photoaging

Objectives: This study addressed whether food and nutrient intakes were correlated with skin wrinkling in a sun-exposed site.

Methods: 177 Greek-born subjects living in Melbourne (GRM), 69 Greek subjects living in rural Greece (GRG), 48 Anglo-Celtic Australian (ACA) elderly living in Melbourne and 159 Swedish subjects living in Sweden (SWE) participating in the International Union of Nutritional Sciences IUNS "Food Habits in Later Life" study had their dietary intakes measured and their skin assessed. Food and nutrient intakes were assessed using a validated semi-quantitative food frequency questionnaire (FFQ). Skin wrinkling was measured using a cutaneous microtopographic method.

Results: SWE elderly had the least skin wrinkling in a sun-exposed site, followed by GRM, GRG and ACA. Correlation analyses on the pooled data and using the major food groups suggested that there may be less actinic skin damage with a higher intake of vegetables ($r_s=-0.31$, $p<0.0001$), olive oil ($r_s=-0.29$, $p<0.0001$), fish ($r_s=-0.24$, $p<0.0001$) and legumes ($r_s=-0.16$, $p<0.0001$), and lower intakes of butter ($r_s=0.46$, $p<0.0001$) and margarine ($r_s=0.24$, $p<0.001$), milk products ($r_s=0.16$, $p<0.01$) and sugar products ($r_s=0.12$, $p<0.01$). Similar findings were obtained using regression analyses, except fish was no longer significant; 32% of the variance for actinic skin damage was predicted by six out of the ten major food groups. In particular, a high intake of vegetables, legumes and olive oil appeared to be protective against cutaneous actinic damage (collectively explaining 20% of the variance); a high intake of meat, dairy and butter appeared to be adverse (explaining <5% of the variance). Prunes, apples and tea explained 34% of variance amongst ACA.

Conclusion: This study illustrates that skin wrinkling in a sun-exposed site in older people of various ethnic backgrounds may be influenced by the types of foods consumed.

INTRODUCTION

The skin is at relatively high risk of damage from reactive oxygen species (ROS) for at least two reasons. Firstly, it is exposed to oxygen by virtue of its rich blood flow and the even higher oxygen tension that occurs in the air at its surface. Secondly, the skin is a light sensitive organ in relation to a number of physiological phenomena including cellular metabolism and differentiation [1], and while it requires light to function appropriately through compounds capable of absorbing light and acting as photosensitizers, it is a rich source of ROS generated by ultraviolet wave length. Peroxidative damage to epidermal cells [2–4] and underlying connective tissue is recognized cosmetically as skin aging. The question is whether food components can modulate this actinic damage. Indeed, it is a proposition of fundamental health significance that, for skin to be an effectively functional organ, it may need to be nourished in a protective way which allows light exposure without damage.

Candidate nutrients that might offset the extent of actinic damage include those which are found in sufficient quantity in skin and are either oxidizable or antioxidant or indirectly influence these activities. The fatty acid composition of the epidermis is 25% unsaturated [5], relatively chemically unstable and susceptible to ROS. Oxidative stress, particularly in

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skin, is induced by photo-damage, inflammation and ischemia-reperfusion. Under these circumstances, many skin antioxidants undergo depletion [6–12] and must be replaced continuously in order to delay the otherwise inevitable deterioration which would lead to skin aging. There is considerable interest in the use of natural compounds in skin protection. Topical application of antioxidants, experimentally, indicates that they may usefully decrease photo-damage and associated inflammation [13–17]. The use of various antioxidants such as vitamin C [13,14], vitamin E (α-tocopherol) [18,19] and their combinations [20,21] as topical photo-protectants has been the subject of various investigations. However, the role of daily food intake in actinic skin damage has not been studied so far.

The work reported here addresses this issue by focussing on older individuals where actinic damage is more manifest and where the differential between individuals is greater. By examining food and nutrient intakes in relation to actinic damage, within and between food cultures, the opportunity to recognize such relationships is increased. We have studied Caucasians of Anglo-Celtic, Greek and Swedish ancestry, living in Australia, Greece and Sweden where actinic exposures differ. Our findings are of interest in relation to the role of food in cutaneous aging, inflammatory skin disorders and skin cancer [22] and to the underlying mechanisms.

SUBJECTS AND METHODS

Subject Selection

The International Union on Nutritional Sciences "Food Habits in Later Life (FHILL) Study" investigated the food habits of approximately 2000 people aged 70 and older in Australia, Greece, China, Japan, Sweden. Study design and subject selection criteria details have been published elsewhere [23,24]. The present report presents findings on skin measurements and food intake on Greek-born subjects living in Melbourne (GRM) (n=177), Greeks living in rural Greece (GRG) (n=69), Anglo-Celtic Australians (ACA) living in Melbourne (n=48) and Swedes living in Goteborg, Sweden (SWE) (n=159).

Food Frequency Questionnaire (FFQ)

Data were collected through interviewer-administered questionnaires, clinical, history and physical examination. Information on the dietary habits of each subject during the previous year was obtained from a validated semi-quantitative food frequency questionnaire (FFQ) [25]. A core FFQ was developed by the principal investigators which was then adapted by co-investigators in different countries and made more culturally sensitive by including culture-specific foods and dishes.

In brief, participants were asked to estimate the average frequency of consumption of each food over the past year in terms of a standard portion size. Portion sizes were specified in units thought to be the most appropriate for the given food. There are three frequency categories, ranging from daily to weekly and monthly. From the average daily intakes of different food items, nutrient intakes were derived using food composition tables. The Australian nutrient analyses program (NUTTAB 1995) was used which is based on Australian food composition tables [26]. This program was modified to include additional Greek dishes [27] and Swedish foods [28]. The food items were treated individually: 254 food items for GRM, 72 foods for GRG, 370 foods for ACA and 210 foods for SWE. The food items were then grouped into minor food groups (55 food groups for GRM or GRG, 77 food groups for ACA and 43 food groups for SWE). Finally, the foods were grouped into 10 major food groups: milk/milk products, meat, fish, legume, cereal, vegetables, fruits, oils/fats, sugar/sugar products and alcohol. Swedish data did not have a separate oil/fats food group because they were included in various recipes/dishes. We were unable to identify the quantity of oil/fat used in dishes in order to generate this food group and thus excluded the Swedish data when analyzing fat intake and skin wrinkling.

Skin Microtopographic Method

A non-invasive skin test was performed on the back of the hand using a cutaneous microtopographic method to assess actinic damage. The back of the hand was chosen as a site for measuring sun-exposure because the method at this site has been developed and validated by Holman and colleagues [29,30]. Furthermore, microtopographic measurements at other convenient sites, such as the face, may be less reliable due to the popular use of facial cosmetics to prevent wrinkling and UV damage.

The silicon rubber impression material (Optosil Flussig, Bayer, Leverkusen, Germany), a viscous white liquid which sets in three to five minutes after addition of a catalyst, was spread on the skin. When the rubber was set, it was stripped slowly and steadily from the skin. This caused no pain to the subjects. So that the assessment was blinded, the microtopographs were assigned random numbers. They were graded according to a six-step scale using a binocular microscope ($\times$10 magnification). The method used was that described by Beagley and Gibson (Fig. 1) [31] to grade cutaneous microtopograph differences which ranged from 1 to 6. A high grade indicates extensive wrinkling and is regarded as an index of severe actinic damage, but this may be influenced by other factors.

Data Analyses

Non parametric Spearman correlation coefficients (r_s) were calculated to consider associations between actinic skin wrinkling and either 10 food major food groups or 43 to 77 minor food groups or 72 to 370 food items or nutrient intakes for each ethnic group and for the pooled data. Multiple regression analyses were also performed to determine the importance of age, gender, smoking and foods (major food groups used in pooled data and food items used with individual ethnic groups) in explaining the variance of actinic skin damage. Throughout the analyses, the SAS statistical package [32] was used.

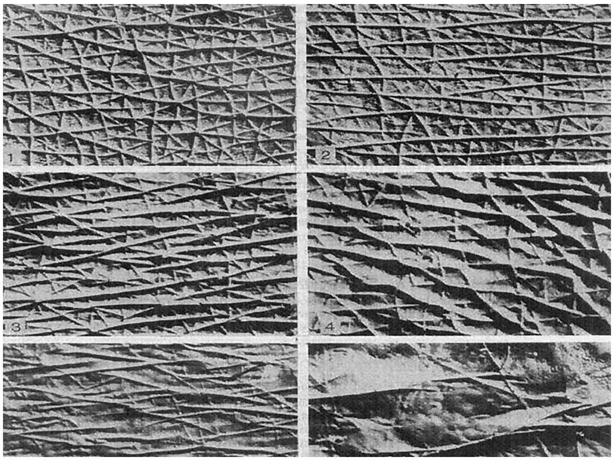

Fig. 1. The Beagley-Gibson (1980) grading of cutaneous microtopographs. (Source: [31] Beagley J and Gibson IM. Changes in skin condition in relation to degree of exposure to ultraviolet light. School of Biology, Western Australia Institute of Technology, Perth, 1980).

RESULTS

Table 1 shows the distribution of the 453 study subjects by ethnic origin, gender, age and degree of skin wrinkling. SWE elderly had the least skin wrinkling in a sun-exposed site, followed by GRM, GRG and ACA. Table 2 shows the mean daily intake of the 10 major food groups.

Actinic Skin Wrinkling, Age, Gender and Smoking Status

Age was positively correlated ($r_s=0.27$, $p<0.0001$) with actinic skin damage; therefore, all analyses were age-adjusted. Even though actinic skin wrinkling was not significantly correlated with gender or smoking by ethnic group or in the pooled data, all analyses controlled for smoking status because smoking has been reported in other studies to increase skin wrinkling [33].

Actinic Skin Wrinkling and Food Intake

Correlation analyses on the pooled data and using the major food groups suggested that there may be less actinic skin damage with a higher intake of vegetables ($r_s=-0.31$, $p<0.0001$), olive oil ($r_s=-0.29$, $p<0.0001$), fish ($r_s=-0.24$, $p<0.0001$) and legumes ($r_s=-0.16$, $p<0.0001$) after controlling for age and smoking. More actinic skin damage was seen with higher intakes of dairy foods ($r_s=0.16$, $p<0.01$), butter ($r_s=0.46$, $p<0.0001$), margarine ($r_s=0.24$, $p<0.001$) and sugar products ($r_s=0.12$, $p<0.01$) (Table 3).

Correlation analyses on the individual ethnic groups were as follows: Greek-born Australians with a low intake of milk and coffee, but a high intake of legumes, mousaka, eggplant dip, garlic, low fat yogurt and polyunsaturated oil had the least skin wrinkling (Table 4). Greek elderly living in rural Greece with a low intake of milk, processed meat, pudding and dessert, fat spread (mainly butter), but a high intake of green leafy vegetables, broad beans and cheese had the least skin damage. Certain foods were negatively associated (protective) with skin wrinkling amongst Anglo-Celtic Australians: sardines, cheese, asparagus, celery, vegetable juice, cherries, grapes, melon, apple, fruit salad, jam, multigrain bread, prunes and tea. Swedish elderly with a low intake of roast beef, meat soup, fried potato, canteloup, grapes, canned fruit, ice cream, cakes and pastries, jam and soft drink, but a high intake of egg, skimmed milk, yogurt, lima bean and spinach pie had better skin.

Table 1. Demographic Characteristic of the Study Population

	GRM n=177)	GRG n=69	ACA n=48	SWE n=159
Gender (%)				
Men	49	42	50	67
Women	51	58	50	33
Age (years)				
Mean[b]	77.57±0.33	77.56±0.55	74.11±0.47	78.15±0.48
Median (min-max)	77 (70–104)	76.5 (70–94)	73 (70–92)	78 (69–96)
Age ≥80 y, n (%)	64 (33.9)	41 (39.4)	16 (11.3)	85 (28.7)
Skin Hand[a]				
Mean[b]	4.87±0.05	5.06±0.10	5.14±0.12	4.74±0.08
Median (min-max)	5.0 (2.7–6.0)	5.3 (3.7–6.0)	5.4 (3.5–6.0)	5.0 (3–6)

[a] Age adjusted.
[b] Data are in mean ± (SE).
GRM=Greek-born Australians living in Melbourne.
GRG=Greeks living in Greece.
ACA=Anglo-Celtic Australians living in Melbourne.
SWE=Swedes living in Sweden.

Table 2. Mean Intake of Major Food Groups (gram/day) by Ethnicity and Total Sample

Food Groups	GRM	GRG	ACA	SWED	TOTAL
Dairy	232±187	184±129	312±163	431±241	284±209
Meat	170±76	97±56	162±91	126±64	136±77
Fish	69±52	60±44	20±19	84±55	61±50
Legumes	86±61	51±36	15±45	23±28	46±52
Cereal	244±97	270±129	243±127	232±137	248±123
Fruit	220±127	180±116	307±179	273±192	238±160
Vegetables	415±172	304±153	210±130	346±158	328±170
Oil and Fats					
Olive	9.4±17.9	30.7±11.9	0.1±0.2	NA	13.3±18.2
Olive oil	18.1±13.3	30.8±12.2	0.0	NA	17.7±15.7
Other oil	3.7±8.0	0.0	0.0	NA	2.6±6.9
Butter	0.8±2.9	0.3±1.3	35.9±7.4	NA	10.2±16.5
Margarine	2.8±4.3	0.0	15.0±12.9	NA	4.8±8.8
Sugar and Sugar Products	89±119	66±88	165±175	227±211	132±166
Alcohol	84±136	104±161	168±319	NA	112±206

GRM=Greek-born Australians living in Melbourne.
GRG=Greeks living in Greece.
ACA=Anglo-Celtic Australians living in Melbourne.
SWE=Swedes living in Sweden.
NA=data not available; Swedish food was entered as recipes which included oil and fats.

Table 3. Correlation (r_s) between Skin Wrinkling and Major Food Groups (Age and Smoking Adjusted)

Food Groups	GRM N=177	GRG N=69	ACA N=48	SWED N=153	TOTAL N=453
Dairy	0.01	0.23*	−0.08	0.11	0.16**
Meat	0.13	−0.18	−0.03	0.05	0.06
Fish	−0.03	−0.04	−0.10	−0.04	−0.24****
Legumes	−0.12	−0.12	−0.16	0.10	−0.16***
Cereal	−0.10	−0.10	−0.16	0.16	0.07
Fruit	−0.06	−0.06	−0.25	0.12	0.03
Vegetables	−0.04	−0.08	−0.07	0.01	−0.31****
Oil & fats	−0.14	0.12	−0.11	NA	−0.21***
Olive	−0.06	0.12	−0.30	NA	−0.32****
Olive Oil	−0.02	0.13	0.00	NA	−0.29****
Other Oil	0.07	0.00	0.00	NA	−0.05
Butter	−0.04	0.31*	−0.06	NA	0.46****
Margarine	−0.04	0.00	−0.11	NA	0.24***
Sugar Products	0.06	0.03	−0.00	0.20*	0.12**
Alcohol	−0.04	−0.12	0.15	NA	−0.00

Significant differences=* $p<0.05$, ** $p<0.01$, *** $p<0.001$, **** $p<0.0001$.
GRM=Greek-born Australians living in Melbourne.
GRG=Greeks living in Greece.
ACA=Anglo-Celtic Australians living in Melbourne.
SWE=Swedes living in Sweden.
NA=Swedish data on oils/fats not available; analyses of oils/fats for total sample does not include Swedish data.

Actinic Skin Wrinkling and Nutrient Intake

Total fat intake was negatively correlated with actinic skin damage ($r_s=-0.10$, $p<0.05$) (Table 5). However, the only fatty acid which was significantly associated with actinic damage was monounsaturated fatty acid in a protective way ($r_s=-0.15$, $p<0.01$). Vitamin C, retinol and intake of minerals such as calcium, phosphorus, magnesium, iron and zinc also appeared to be protective against cutaneous actinic damage (age and smoking adjusted).

Food and Nutrient Predictors of Actinic Skin Damage (Multiple Regression Analyses)

Multiple regression analyses on the pooled data indicated that about 32% of the variance for actinic skin damage was

Table 4. Correlation between Actinic Skin and Food Item Intake and Mean Intake of Food Items by Ethnicity

Ethnicity	Food Items	r_s	Mean±STD (g or mL/day)
GRM	Evaporated Milk	0.12*	135±157
	Instant Coffee	0.19**	0.45±0.79
	Legumes	−0.11	68±52
	Mousaka	−0.17*	2.0±4.9
	Eggplant Dip	−0.16*	0.22±1.10
	Garlic	−0.20**	1.21±2.70
	Yoghurt (low fat)	−0.14*	5.14±25.29
	Polyunsaturated oil	−0.16*	1.16±4.82
GRG	Milk	0.25*	100±107
	Processed Meat	0.22	1.64±10.47
	Pudding/Dessert	0.24*	6.92±14.61
	Fat Spread	0.31*	0.27±1.34
	Green Leafy Vegetables	−0.21	62.50±54.56
	Broad Bean Boiled	−0.22	2.77±3.46
	Cheese, (Kefalotiri)	−0.24*	3.46±7.40
ACA	Sandwich Meat	0.43**	0.47±1.80
	Mashed Potatoes	0.44**	27.03±57.11
	Cocoa	0.35*	5.46±25.17
	Salmon	0.35*	0.25±1.42
	Low Alcohol Beer	0.39*	39.28±107.1
	Tin Sardines	−0.34	1.20±2.38
	Phila Cheese	−0.35*	0.11±0.61
	Asparagus	−0.36*	1.73±4.05
	Celery	−0.46**	7.56±10.12
	Vegetables Juice	−0.35*	13.50±87.24
	Cherries	−0.46**	0.57±1.69
	Grapes	−0.34	5.46±9.94
	Melon	−0.44**	5.46±14.01
	Apple	−0.37*	0.44±1.60
	Fruit Salad	−0.36*	7.63±17.62
	Multi Grain Bread	−0.50**	19.17±47.92
	Dried Prunes	−0.42**	1.64±5.96
	Tea	−0.54***	679±520
SWE	Roast Beef	0.16*	34.5±24.4
	Meat Soup	0.25*	10±15
	Fried Potato	0.24*	9±18
	Cantaloupe	0.19*	3±6
	Grapes	0.20*	12±23
	Canned Fruit	0.23*	6±13
	Ice Cream	0.20*	8±14
	Plain Cake	0.18*	14±23
	Marmalade Jam	0.20*	12±15
	Soft Drink	0.27*	60±151
	Brown Meat	0.21*	3±8
	Danish Pastry	0.17*	3±9
	Sweet Pastry	0.16*	2±5
	Egg	−0.17*	16±19
	Skimmed Milk	−0.15	132±204
	Yogurt	−0.14	5.6±33.2
	Chicken Soup	−0.20**	0.4±2.8
	Lima Bean Casserole	−0.21**	0.2±1.6
	Spinach pie	−0.19*	0.2±1.5
	Water	−0.17*	539±464

Significant differences=* $p<0.05$, ** $p<0.01$, *** $p<0.001$, **** $p<0.0001$.
GRM=Greek-born Australians living in Melbourne.
GRG=Greeks living in Greece.
ACA=Anglo-Celtic Australians living in Melbourne.
SWE=Swedes living in Sweden.

predicted or could be explained by eight out of the ten major food groups. In particular, a high intake of oil (mainly olive oil), legumes, fish, vegetables and cereal appeared to be protective against cutaneous actinic damage (collectively explained 20% of the variance) (Fig. 2). In contrast, a high intake of meat, sugar and its products and dairy products appeared to be adverse (explaining <5% of the variance). In addition, intakes of nutrients such as fat, carbohydrate, vitamin C, retinol, iron, phosphorus and magnesium predicted 25% of the variance for actinic damage (Table 6a). When the type of fats (polyunsaturated, monounsaturated, saturated) was put into the model, the variance increased to 39%; monounsaturated fats and zinc appeared to be protective against photoaging (explaining 10% of the variance) while saturated fats and vitamin C appeared to be adverse (explaining 10% of the variance) (Table 6b). When multiple regression analyses were run with minor food groups, the predictive power of food was 10% for GRM, 36% for GRG, 85% for ACA and 41% for SWE. GRM with high intakes of nuts, olives, low fat spread and dips, but low intakes of milk, crispbread and soups had the least actinic damage (Table 7). GRG subjects with a high intake of green leafy vegetables, garlic, rice and chicken, but a low intake of fat spread (mainly butter), shellfish and processed meat had the least cutaneous damage. Three food groups, namely dried fruits, apples and tea, explained 34% of variance amongst ACA (Table 8). SWE elderly with a high intake of vegetable dishes, eggs, water, but a low intake cereal, bread and soft drinks had the least skin damage (Table 7).

DISCUSSION

Foods Protective Against Skin Wrinkling

This was a cross-sectional study to investigate the association between actinic skin damage and dietary intake. We found that Swedish elderly had the least skin wrinkling, followed by Greeks in Melbourne, Greeks in rural Greece and Anglo-Celt Australians. Despite genetic differences, other factors such as geographical area and life style differences might influence the skin. Swedish people, for example, tend to seek sunlight due to the short period of summer. Overall, our finding suggest that subjects with a higher intake of vegetables, olive oil and monounsaturated fat and legumes, but a lower intake of milk/milk products, butter, margarine and sugar products had less skin wrinkling in a sun-exposed site. There may be covariance between food categories in which a cuisine may operate on skin biology.

Smoking was not a significant predictor of skin wrinkling in this cohort of elderly people. We suspect that the high vegetable intakes of the smokers (mean 308g/day) may have masked or antagonized the effects of smoking on skin biology. Nevertheless, smoking has been found to influence skin wrinkling in

Table 5. Correlation between Actinic Skin Damage and Nutrients (Age and Smoking Adjustment)

Nutrients	GRM	GRG	ACA	SWED	TOTAL
Protein	0.05	−0.15	−0.08	0.06	0.01
Fat	−0.04	0.11	−0.03	0.12	−0.10*
SFA	0.03	0.07	0.01	0.15	−0.03
MUFA	−0.09	0.12	0.01	0.11	−0.15**
PUFA	−0.07	0.07	−0.18	0.05	−0.08
Cholesterol	0.14	−0.01	0.00	NA	0.00
Carbohydrate	−0.02	−0.14	−0.18	0.17*	0.09
Calcium	−0.03	−0.02	0.10	0.07	−0.25****
Phosphorus	0.00	−0.10	−0.01	0.06	−0.28****
Magnesium	−0.11	−0.17	0.11	0.12	−0.35****
Iron	−0.09	0.02	0.15	0.12	−0.25****
Zinc	0.03	−0.10	0.13	0.11	−0.25****
Retinol	0.10	0.01	−0.35	0.16*	−0.16**
Vitamin C	0.01	−0.07	0.13	0.08	−0.30****
Alcohol	−0.03	−0.12	0.07	−0.00	−0.04

Significant differences=* $p<0.05$, ** $p<0.01$, *** $p<0.001$, **** $p<0.0001$.
GRM=Greek-born Australians living in Melbourne.
GRG=Greeks living in Greece.
ACA=Anglo-Celtic Australians living in Melbourne.
SWE=Swedes living in Sweden.
NA=data not available.
SFA=saturated fatty acid.
MUFA=monounsaturated fatty acid.
PUFA=polyunsaturated fatty acid.

Fig. 2. Food predictors of skin wrinkling. Multiple regression analyses shows 32% of the variance was predicted by food intake. Oils, legumes, fish, vegetables and cereal appeared to be protective (collectively explained 20% of the variance). In contrast, a high intake of meat, sugar products and dairy appeared to be adverse (explaining 5% of the variance). Age and smoking explained 7% of the variance.

Table 6a. Nutrient Predictors of Actinic Skin Damage[a]

Variable	Parameter Estimate	Standard Error	Partial R^2
Age	−0.0226	0.0117	0.0045§
Smoking	−0.4032	0.0795	0.1237****
Nutrients			
Retinol	−0.0003	0.0001	0.0357****
Iron	−0.0151	0.0063	0.0297***
Vitamin C	−0.0021	0.0010	0.0210***
Carbohydrate	0.0029	0.0011	0.0093*
Fat	−0.0121	0.0038	0.0160*
Phosphorus	0.0011	0.0004	0.0308***
Magnesium	−0.0031	0.0014	0.0086*
% Variance explained by the model R^2 (×100)=25%			

[a] Variables included in the analysis were age, gender, smoking and nutrients (fat as total fat).
Significant level was set at 0.15 for variables to be entered into the model.
Significant level for F-test at which values are different from zero=* $p<0.05$, ** $p<0.01$, *** $p<0.001$, **** $p<0.0001$, § $p<0.13$.
Smoking status was classified as 3=smoker, 2=ex-smoker, 1=non-smoker, so negative sign means non-smokers are less likely to have wrinkled skin.

other studies [33]. We therefore proceeded to adjust for smoking to enable us to consider the effect of vegetables on skin in their own right.

The former group of foods may have partly contributed to the less skin wrinkling due to their high content of antioxidant vitamins and phytochemicals. A protective effect of antioxidants such as vitamin C, vitamin E, retinoic acid, co-enzyme Q10 as a topical treatment and prevention of photoaging has been documented [19,34,35]. It is generally accepted that, being the largest surface area of the body, skin is a major target of oxidative stress. Skin is very susceptible to oxidative damage due to its high content of lipids, proteins and DNA, which are extremely sensitive to the oxidation process [36]. However, by consuming vegetables, legumes and olive oil, the oxidation of the skin could be protected against. In the Greek cuisine, vegetables and legumes are consumed with olive oil. This combination of foods may provide further benefit in preventing skin wrinkling if the oil assists in the absorption of fat-soluble antioxidant vitamins and phytochemicals, such as vitamin E, lycopene and isoflavones. Fish intake was significantly correlated with less skin wrinkling, but this association was not

Table 6b. Nutrient Predictors of Actinic Skin Damage[a]

Variable	Parameter Estimate	Standard Error	Partial R^2
Smoking	−0.4032	0.0795	0.1843****
Nutrients			
MUFA	−0.0422	0.0060	0.1002****
SFA	0.0553	0.0086	0.0917****
Zinc	−0.0346	0.0155	0.0072Ì
Vitamin C	0.0017	0.0009	0.0086*
% Variance explained by the model R^2 (×100)=39%			

[a] Variables included in the analysis were age, gender, smoking and nutrients (fat as fatty acids).
Significant level was set at 0.15 for variables to be entered into the model.
Significant level for F-test at which values are different from zero=* $p<0.05$, ** $p<0.01$, *** $p<0.001$, **** $p<0.0001$, Ì $p<0.06$.
Smoking status was classified as 3=smoker, 2=ex-smoker, 1=non-smoker, so negative sign means non-smokers are less likely to have wrinkled skin.
MUFA=monounsaturated fatty acid.
PUFA=polyunsaturated fatty acid.

observed in the multiple regression analyses. The fact that fish is also a significant source of n-3 polyunsaturated fatty acids is of interest. But whether fish is protective against actinic damage may depend on what it is eaten with. If fish is eaten with salad or cooked vegetables, then it may be the antioxidant carotenoids and other compounds in the plant foods which are offering protection. Fish itself can also contain a significant amount of antioxidants including carotenoids contributing to fish color, Co-Q10 (ubiquinone) and vitamin E along with components like fish sterols which may influence skin biology. n−3 F fatty acids have been found to be useful in the treatment of psoriasis [37].

For each ethnic population, vegetables, legumes and fermented milk products were negatively correlated or predictive of photoaging. In particular, full-fat milk (as opposed to skim milk, cheese and yogurt), red meat (especially processed meat), potatoes, soft drinks/cordials and cakes/pastries were associated with extensive skin wrinkling. In contrast, eggs, yogurt, legumes (especially broad and lima beans), vegetables (especially green leafy/spinach, eggplant, asparagus, celery, onions/leeks and garlic), nuts, olives, cherries, grapes, melon, dried fruits/prunes, apples/pears, multigrain bread, jam, tea and water were associated with less photoaging. Three food groups, namely dried fruits (prunes), apples and tea, explained 34% of variance amongst ACA.

Fruits, vegetables, tea (as well as herbs) with diverse pharmacological properties have been shown to be rich sources of phythochemicals with potential for the prevention and treatment of noncommunicable disease. Recent studies *in vitro* have shown that procyanidins in grape seeds possess anti-inflammatory and anti-arthritis properties and prevent heart disease and skin aging [38,39]. In other studies, polyphenols, which are also found in prunes, apples and tea, have been shown to exert a much stronger oxygen free radical scavenging effect than vitamins C and E [40,41], and to prevent ultraviolet-C-induced peroxidation [42].

Table 7. Food Predictors of Actinic Skin Damage by Ethnicity

Ethnicity	Variables	Parameter Estimate	Standard Error	Partial R^2
GRM	Evaporated Milk	0.0066	0.0034	0.0249**
	Nuts	−0.0070	0.0039	0.0196*
	Crispbread	0.0079	0.0039	0.0164*
	Olives	−0.0052	0.0032	0.0158*
	Low Fat Spread	−0.0758	0.0451	0.0108†
	Dips	−0.0276	0.0169	0.0091§
	Soups Broth Type	0.0016	0.0011	0.0087§
	% Variance explained by the model R^2 (×100)=10%			
GRG	Smoking	0.2067	0.0981	0.0347Ì
	Fat Spread	0.1510	0.0482	0.0735*
	Green Leafy Vegetables	−0.0043	0.0015	0.0838**
	Garlic	−0.164	0.0103	0.0444Ì
	Shellfish	0.0354	0.0169	0.0325Ì
	Processed Meat	0.0138	0.0059	0.0354Ì
	Rice	−0.0081	0.0046	0.0254‡
	Chicken/Turkey	−0.0055	0.0035	0.0270†
	% Variance explained by the model R^2 (×100)=36%			
SWE	Age	0.0454	0.0152	0.0305†
	Gender	−0.3666	0.1742	0.0387*
	Smoking	−0.5154	0.2032	0.0234§
	Vegetable Mix Dish	−0.0044	0.0023	0.0453*
	Eggs	−0.0124	0.0044	0.0391*
	Soft Drinks & Cordials	0.0010	0.0006	0.0397*
	Flower Vegetables	0.0062	0.0031	0.0271©
	Fungi	−0.0426	0.0162	0.0267‡
	Dessert and Pudding	0.0029	0.0012	0.0373*
	Water	−0.0005	0.0002	0.0317Ì
	Bread	0.0028	0.0018	0.0221†
	Tea	0.0718	0.0718	0.0298*
	Green Leafy Vegetables	−0.1238	0.0559	0.0168£
	Chicken and Turkey	−0.0165	0.0095	0.0228†
	Root Vegetables	0.0018	0.0011	0.0191©
	% Variance explained by the model R^2 (×100)=41%			

[a] Variables included in the analyses were age, gender, smoking and minor food groups.
[b] Major food groups.
Significant level was set at 0.15 for variables to be entered into the model.
Significant level for F-test at which values are different from zero=* $p<0.05$, ** $p<0.01$, *** $p<0.001$, **** $p<0.0001$, ¥ $p<0.1088$, § $p<0.1189$, © $p<0.09$, £ $p<0.1475$.
Smoking status was classified as 1=smoker, 2=ex-smoker, 3=non-smoker, so negative sign means non-smokers are less likely to have wrinkled skin.

Due to their antioxidant activity, polyphenols present in plant food [43–47] such as tea, apples, onions, garlic and eggplant appear to be partially responsible for many of the protective effects against oxidative stress of the skin. Recent *in*

Table 8. Food Predictors of Actinic Skin Damage amongst Anglo-Celtic Australian

Variables	Parameter Estimate	Standard Error	Partial R^2
Smoking	−0.6747	0.0600	0.0379*
Food groups[b]			
Dried Fruits	−0.0481	0.0040	0.1672**
Apples & Pears	−0.0199	0.0011	0.0933*
Tea	−0.0005	0.0002	0.0826*
Salad Dressing	0.1233	0.0140	0.0572*
Leafy Green Vegetables	−0.0523	0.0064	0.0626*
Spirit and Liqueurs	−0.0371	0.0068	0.0472*
Nuts and Seeds	0.0579	0.0182	0.0518*
Ice Cream	0.0599	0.0042	0.0306Ì
Onion & Leeks	−0.0368	0.0099	0.0340*
Jam & Sweet Spread	−0.0160	0.0014	0.0280*
Other Confectionery	−0.1168	0.0118	0.0115§
Deli Meats	−0.2157	0.0762	0.0155©
Chocolate	−0.0438	0.0196	0.0167†
Bread & Rolls	−0.0030	0.0016	0.0100Ì
% Variance explained by the model R^2 (×100)=85%			

[a] Variables included in the analyses were age, gender, smoking and minor food groups.
[b] Minor food groups.
Significant level was set at 0.15 for variables to be entered into the model.
Significant level for F-test at which values are different from zero=* $p<0.05$, ** $p<0.01$, *** $p<0.001$, **** $p<0.0001$, Ì $p<0.06$, † $p<0.07$, ‡ $p<0.08$; © $p<0.09$, ¥ $p<0.1088$, £ $p<0.1075$, § $p<0.1689$.
Smoking status was classified as 1=smoker, 2=ex-smoker, 3=non-smoker, so negative sign means non-smokers are less likely to have wrinkled skin.

vitro evidence from Tufts University has identified prunes, strawberries/berries, cherries, tea and the like to have the highest antioxidant activity compared to many other foods. Flavonoids are among the most potent plant antioxidants because of their involvement in antiradical activity [48]. In this study, legume consumption also appeared to be protective against actinic damage; this may be partly explained by their phytoestrogen content. Phytoestrogens have recently been identified to act as antioxidants [49,50].

Foods Associated with More Skin Wrinkling

A higher intake of full-fat milk, sweet milk desserts, icecream, but not skim milk, yogurt or cheese, was associated with a greater degree of photoaging. These foods explained only 5% of the variance. This suggests that these foods may need to be consumed with other protective foods, such as fruit, vegetables, fish and legumes, to minimize any adverse effects on skin health. Butter was also significantly correlated with more photoaging and explained more than 50% of the variance for skin wrinkling in the pooled data when the analysis only included dietary fats and no other food groups. Even though saturated fat is known to be resistant to oxidation, foods high in saturated fat did not appear to protect against photoaging. There is evidence that sugar and sugar products may contribute to a deterioration in skin health via the glycosylation of proteins [51,52] in the skin, which in turn may contribute to skin wrinkling and photoaging.

Nutrients and Skin Wrinkling

In terms of nutrients, total dietary fat intake and a higher intake of monounsaturated fatty acids were negatively associated with photoaging. About 25% of the fatty acid composition of the epidermis consists of monounsaturated fatty acids [5]. The polyunsaturated fatty acids in the cell membranes are prone to oxidation; in contrast, monounsaturated fats and saturated fats resist oxidation [35]. A high intake of monounsaturated fat may increase the content of monounsaturated fatty acids in the epidermis, which may in turn assist in reducing oxidative damage. This may explain why a higher intake of olive oil was associated with less photoaging and a higher intake of polyunsaturated margarine was associated with more photoaging. Intakes of micronutrients such as iron, zinc, calcium, phosphorus, magnesium, retinol and vitamin C were protective against actinic skin damage. Intakes of such nutrients may partly increase the endogenous antioxidative capacity of the skin. In the regression analyses, vitamin C was positively associated with skin wrinkling (Table 6b). Vitamin C can act as a pro-oxidant at levels above the recommended dietary intake [53]. The vitamin C intakes of the subjects (127 mg/day) may have reached the level where vitamin C acts as a pro-oxidant. Pro-oxidants would theoretically increase the susceptibility to photoaging. There is growing evidence that the important antioxidants in human diets are much more than the vitamins C, E or beta-carotene [54]; our finding supports this view.

CONCLUSION

This study illustrates that skin wrinkling in a sun-exposed site in older people of various ethnic backgrounds may be influenced by the types of foods consumed. Correlation and regression analyses on the minor food groups and food items for each ethnic group identified the following foods to be positively associated with cutaneous actinic skin damage: full-fat milk (as opposed to skim milk, cheese and yogurt), red meat (especially processed meat), potatoes, soft drinks/cordials, cakes/pastries. Negative associations were found with eggs, yogurt, legumes (especially broad and lima beans), vegetables (especially green leafy/spinach, eggplant, asparagus, celery, onions/leeks, garlic), nuts, olives, cherries, melon, dried fruits/prunes, apples/pears, multigrain bread, jam, tea and water. Three food groups, namely dried fruits, apples and tea, explained 34% of variance amongst ACA. For nutrients, higher intakes of total fat, especially monounsaturated fat, vitamin C, calcium, phosphorus, magnesium, iron, zinc and retinol were correlated with less actinic skin damage.

An intervention study is needed to investigate whether cutaneous actinic damage could be prevented in part with higher intakes of vegetables (especially green leafy, garlic/onions, celery), legumes, olive oil, total fat (mainly monounsaturated), apples/pears, prunes, tea and possibly fish, cherries, melons, minerals, vitamin C and retinol.

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