A healthy diet in women is associated with less facial wrinkles in a large Dutch population-based cohort

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Background: Little is known about the effects of different dietary patterns on facial wrinkling.

Objective: We aimed to investigate the association between diet and facial wrinkles in a population-based cohort of 2753 elderly participants of the Rotterdam study.

Methods: Wrinkles were measured in facial photographs by digitally quantifying the area wrinkles occupied as a percentage of total skin area. Diet was assessed by the Food Frequency Questionnaire. Adherence to the Dutch Healthy Diet Index (DHDI) was calculated. In addition, we used principal component analysis (PCA) to extract relevant food patterns in men and women separately. All food patterns and the DHDI were analyzed for an association with wrinkle severity using multivariable linear regression.

Results: Better adherence to the Dutch guidelines was significantly associated with less wrinkles among women but not in men. In women, a red meat and snack–dominant PCA pattern was associated with more facial wrinkles, whereas a fruit-dominant PCA pattern was associated with fewer wrinkles.

Limitations: Due to the cross-sectional design of our study, causation could not be proven. Other health-conscious behaviors of study participants could have influenced the results.

Conclusion: Dietary habits are associated with facial wrinkling in women. Global disease prevention strategies might benefit from emphasizing that a healthy diet is also linked to less facial wrinkling. (J Am Acad Dermatol 2019;80:1358-63.)

Key words: diet; Dutch Healthy Diet Index; facial wrinkling; healthy lifestyle; nutrition; principal component analysis; Rotterdam study; skin aging.

Maintaining a healthy body and youthful appearance is increasingly becoming popular because the longevity and wealth of the global population is still rising. The rise of functional foods claiming various skin benefits suggests that certain nutrients could help to prevent skin aging and enhance cosmesis.[1]

While several small studies have investigated the effects of dietary supplements on skin aging,[2-4] large nutritional studies on this topic are lacking. To our

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Conflicts of interest: Although no products were tested, it is possible that this manuscript could promote products or foods that reduce the appearance of wrinkles, which could lead to financial gain for Unilever of whom Dr Gunn is an employee.

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knowledge, only 3 previous studies have investigated features of skin aging in association with diet.[5-7] In these studies, intake of vegetables, foods high in carotenoids and vitamin C, olive oil, linoleic acid, and fish were associated with less photoaging and intake of saturated fats and sugar with more wrinkling.

On the basis of these observations, a healthy diet appears associated with less skin aging. However, in these previous studies, researchers investigated separate nutrients or food groups that were prone to false-positive associations because of co-linearity with the causative nutrient and the interaction between single nutrients. Also, the effect sizes of single nutrients are often small, making it difficult to discover associations. Studying complete dietary patterns in epidemiologic nutritional research, therefore, can be preferred over studying single nutrients.[8] Dietary pattern analysis can be conducted a priori, in which the healthiest pattern is predefined using existent guidelines, eg, the Dutch Healthy Diet Index (DHDI).[9] However, in case of little prior knowledge, an a posteriori approach, in which formed patterns were data driven, could be more appropriate, eg, using a principal component analysis (PCA).[8]

CAPSULE SUMMARY

- Little is known about the impact of nutrition on youthful appearance.
- Adherence to the recommended healthy diet was associated with less wrinkling and the unhealthy diet with more facial wrinkling in women.
- Dietary recommendations for skin aging preventing strategies could in addition help to improve overall health.

In our study, we investigated the association between digitally quantified facial wrinkling, dietary patterns, and healthy lifestyle parameters in a large population-based cohort of 2753 elderly participants of the Rotterdam study using both an a priori and an a posteriori approach.

METHODS

Study population

Participants were selected from the Rotterdam study, a prospective population-based cohort study in Rotterdam, the Netherlands. The Rotterdam study was approved by the institutional review board (Medical Ethics Committee) of the Erasmus Medical Center and by the review board of The Netherlands Ministry of Health, Welfare, and Sports. Objectives and details of the study design have been described elsewhere.[10]

During 2010-2014, standardized high-resolution digital facial photographs were taken of 4649 participants by trained physicians. From these pictures, we obtained wrinkle data for 3831 participants, and nutrition data was available for 2813 of these participants. We excluded 60 of the 2813 participants because of unrealistic caloric intakes (<500 and >5000 kcal/day). The remaining 2753 participants were included in our analysis.

Wrinkles

Using full-face photographs, we digitally quantified the area detected as wrinkles as a percentage of the total facial skin area using a semi-automated script in MATLAB (MathWorks, Natick, MA). Our wrinkle data has been validated and utilized in other analyses.[11-13]

Dietary intake and food pattern analysis

Dietary intake was assessed using a validated semi-quantitative Food Frequency Questionnaire.[9] We defined the a priori healthiness of the diet in our population using the DHDI.[14,15] For the a posteriori approach, we used a PCA (Supplementary Appendix; available at http://www.jaad.org).

Statistical analysis

For all analyses, we used a basic (age adjusted) or a multivariable linear regression model stratified by sex because men and women have different risk factors for wrinkling.[11] First, we tested the effect of known and possible new risk factors (physical activity, daily energy intake) on facial wrinkling. Second, all PCA patterns and DHDI were used to test associations between wrinkles and diet (Supplementary Appendix).

Additional analysis

Ultraviolet (UV) exposure data was missing for 45% of the study participants. In a complete case analysis in women (N = 849), we adjusted our main analysis for UV exposure variables (Supplementary Appendix). Association tests with physical activity were additionally adjusted for UV to reduce residual confounding. Also, we tested single food groups separately in women to understand which food groups drive the association of a food pattern (Supplemental Table I; available at http://www.jaad.org).

RESULTS

The study population consisted of 2753 middle-aged and elderly Dutch men (41%) and women (59%), with a median age of 67.3 (interquartile range

Abbreviations used:

CI: confidence interval
DHDI: Dutch Healthy Diet Index
IQR: interquartile range
PCA: principal component analysis
UV: ultraviolet

[IQR] 62.6-72.3) years. Known risk factors, such as age, sex, body mass index, and smoking status, showed a significant association with wrinkle area in both the basic and the multivariable model. Of the newly investigated risk factors, daily energy intake did not have an effect on wrinkles, even when not adjusting for body mass index. Strikingly, more physical activity resulted in more wrinkles in the multivariable model in men and in women (Table I).

Adherence to the predefined healthy diet, shown by higher DHDI scores, resulted in significantly less facial wrinkling in women (−4.19%, 95% confidence interval [CI] −7.30 to −1.08; Table II) but not men. In women and in men, we extracted 4 and 3 food patterns, respectively, using PCA of the 34 food groups. The first 3 PCA patterns in women and men were comparable. The first pattern consisted of high consumption of mainly healthy food groups (including vegetables, fish and poultry, nuts and seeds, and mineral water) and wine. The second pattern was an unhealthy pattern consisting of consumption of mainly meat, grains, snacks, soft drinks, coffee, and other alcoholic drinks. The third pattern was an intermediate mix of healthy and unhealthy foods that resembled a typical Dutch diet, which included a high intake of cheese, potatoes, grains, and fats (Table III). The fourth PCA pattern, which was seen in women, was a diet high in fruit, supplemented with yogurt, milk, and some vegetables (Table III).

In men, no a posteriorly defined food pattern was associated with increased or decreased wrinkling, but in women, the unhealthy pattern was significantly associated with more wrinkling (3.32%, 95% CI 0.06 to 6.68) and the fruit pattern was significantly associated with less facial wrinkling (−3.20%; 95% CI −6.25 to −0.06) (Table II). We also calculated the same fruit PCA pattern in men, but there was no significant protective effect on wrinkles for this food pattern (−0.41%, 95% CI −3.67 to 2.96).

UV exposure and physical activity did not significantly alter effect size of food patterns in our sensitivity analysis (data not shown). The single food group analysis detected single food groups associated with facial wrinkling (Supplemental Table I).

DISCUSSION

We found a healthy diet to be associated with less facial wrinkling in women, shown by both the predefined DHDI and the healthy fruit pattern in women. In addition, the unhealthy food pattern was associated with more facial wrinkling in the same group, providing more evidence of the link between a healthy diet and wrinkling. These observations are in-line with previous studies showing that high intake of animal source products, fats, and carbohydrates increased skin aging[5,6] and vitamin C and carotenoids decreased winkles.[7]

Both a healthy diet preventing wrinkles and an unhealthy diet aggravating wrinkles were found in women but not in men. Men and women are known to show distinct wrinkling patterns and different dietary habits, which could help explain the sex differences in the wrinkle associations.[11,16] Although, no wrinkle-protecting effect was found when applying the fruit-based food pattern to the male subgroup, this difference might be explained by men consuming less fruits than women, making an association harder to detect.

The posteriorly defined healthy food PCA pattern was not associated with less facial wrinkling in women. The single food group analysis showed that of nutrients in the healthy PCA pattern, yellow vegetables and soy were significantly associated with less wrinkling and wine was significantly associated with more wrinkling. Thus, this common food pattern includes food groups that associate with both less and greater wrinkling, and is therefore not associated with wrinkling overall.

Examining patterns of nutrient intake can be valuable in the interpretation of nutrition associations. For example, although processed meat does not associate with wrinkling in the single nutrient analysis, it does associate via the unhealthy PCA pattern in women, which suggests that in concert with other (unhealthy) nutrients, processed meat could be promoting skin wrinkling.

The biologic mechanism responsible for the association between skin wrinkling and unhealthy diet could be increased oxidative stress load,[17] an upregulated inflammatory state,[18] or the effect of advanced glycation endproducts, which can disrupt cell metabolism and weaken antioxidant defense.[19] In contrast, vitamins and flavonoids in a healthy diet provide protection from photoaging and stimulate collagen production and DNA repair mechanisms.[20,21]

We found more physical activity to be associated with more facial wrinkling in both sexes. As many sports are practiced outside, UV exposure could play

Table I. Population characteristics of women (N = 1613) and men (N = 1140) included in study

Characteristic	Value	Wrinkle % change, univariable analysis	95% CI*	Wrinkle % change, multivariable analysis	95% CI†
Women					
Wrinkle % change, median (IQR)	3.7 (2.3-5.8)				
Age, y, median (IQR)	67.1 (62.5-72.0)	4.524	**4.102 to 4.948**	4.726	**4.294 to 5.159**
Daily energy intake, Kcal, mean (SD)‡	2027 (636)	0.0004	−0.004 to 0.005	−0.001	−0.005 to 0.004
Physical activity (MET), hr/wk, median (IQR)§	46.6 (18.8-87.4)	0.093	**0.029 to 0.157**	0.082	**0.019 to 0.144**
BMI, kg/m^2, mean (SD)	27.4 (4.8)	−2.138	**−2.726 to −1.546**	−2.057	**−2.652 to −1.458**
Smoking, %					
Never	634 (39)	Referent	—	Referent	—
Former	739 (46)	−1.392	−6.992 to 4.545	10.413	**3.798 to 17.450**
Current	237 (15)	32.692	**22.300 to 43.967**	37.473	**25.978 to 50.016**
Education,‖ %					
Low	140 (9)	Referent	—	Referent	—
Medium	1087 (67)	2.235	−4.018 to 8.894	−3.142	−12.156 to 6.798
High	370 (23)	−5.111	−11.610 to 1.865	−9.263	−18.754 to 1.337
Men					
Wrinkle % change, median (IQR)	4.6 (3.1-6.5)				
Age, y, median (IQR)	67.7 (62.7-72.7)	2.395	**1.980 to 2.811**	2.555	**2.113 to 2.999**
Daily energy intake, Kcal, mean (SD)‡	2312 (706)	0.005	0.0003 to 0.009	0.004	−0.001 to 0.008
Physical activity (MET), hr/wk, median (IQR)§	40.7 (17.9-73.3)	0.111	**0.035 to 0.186**	0.108	**0.033 to 0.183**
BMI, kg/m^2, mean (SD)	27.4 (3.5)	−1.898	**−2.757 to −1.031**	−1.816	**−2.680 to −0.946**
Smoking, %					
Never	242 (21.2)	Referent	—	Referent	—
Former	679 (59.6)	−6.149	−11.978 to 0.066	0.524	−6.935 to 8.620
Current	218 (19.1)	13.610	**5.102 to 22.807**	15.279	**4.898 to 26.686**
Education,‖ %					
Low	67 (5.9)	Referent	—	Referent	—
Medium	630 (55.3)	0.858	−5.131 to 7.225	9.157	−3.092 to 23.017
High	428 (37.5)	1.194	−5.008 to 7.800	8.463	−4.140 to 22.721

Significant results ($P \leq .05$) are bold.

BMI, Body mass index; *CI*, confidence interval; *IQR*, interquartile range; MET, metabolic equivalent of task; *SD*, standard deviation.

*Univariable analysis was adjusted for technical variation and age.

†Multivariable analysis was adjusted for technical variation, age, daily energy intake, physical activity, BMI, smoking status, and education.

‡Daily energy intake in kilocalories. 1 Kcal = 4184 joules.

§MET hours per week is a physiologic measure expressing the energy cost of physical activity.

‖Categories of education were low (primary education), medium (lower vocational education, lower secondary education, intermediate vocational education), and high (general secondary education, higher vocational education, university).

Table II. Association of Dutch Healthy Diet Index and dietary patterns with facial wrinkles[†]

	Women, N = 1613			Men, N = 1140		
Dietary pattern	**Wrinkle % change***	**95% CI**	***P***	**Wrinkle % change***	**95% CI**	***P***
A priori						
Dutch Healthy Diet Index	−4.48	**−7.58 to −1.36**	**.005**	0.61	−2.79 to 4.03	.724
A posteriori						
Healthy	−0.56	−3.55 to 2.54	.723	0.76	−2.62 to 4.26	.664
Unhealthy	3.32	**0.06 to 6.68**	**.046**	2.72	−0.58 to 6.12	.107
Intermediate	−1.84	−5.39 to 1.83	.322	−0.67	−4.79 to 3.63	.755
Fruit	−3.20	**−6.25 to −0.06**	**.046**	-	-	-

P values <.05 were considered significant and are presented in bold.
CI, Confidence interval.
*Increase or decrease in percentage of wrinkle area percentage (Δ%) per 10 points increase on the DHDI, when committing to a dietary pattern.
[†]Adjusted for technical variation, age, physical activity, body mass index, daily energy intake, smoking, and education level.

Table III. Dietary patterns (eigenvalue ≥1.5) with factor loadings of the contributing food groups in women and men

	Women, N = 1613				Men, N = 1140		
Category	**Healthy**	**Unhealthy**	**Intermediate**	**Fruit**	**Healthy**	**Unhealthy**	**Intermediate**
Citrus fruits	-	-	-	**0.836**	**0.448**	−0.418	-
Other fruits	-	-	-	**0.826**	**0.515**	−0.455	-
Yellow vegetables	**0.754**	-	-	0.204	**0.718**	-	-
Green leafy vegetables	**0.739**	-	-	-	**0.691**	-	-
Other vegetables	**0.688**	-	-	-	**0.653**	-	-
Pulses	0.227	-	-	-	-	-	-
Milk	-	-	-	0.251	-	-	0.323
Yoghurt	-	-	-	0.208	0.267	−0.230	-
Cheese	-	0.370	-	-	-	-	0.343
Soy	0.297	−0.277	-	-	-	-	-
Nuts and seeds	-	-	-	-	0.317	-	-
Eggs	-	0.350	-	-	-	0.228	-
Poultry	0.262	0.252	-	-	0.271	0.251	-
Unprocessed meat	-	**0.546**	-	-	-	**0.471**	-
Processed meat	-	**0.575**	-	-	-	**0.505**	0.306
Lean fish	0.394	0.227	-	-	0.339	0.289	-
Fatty Fish	**0.469**	-	-	-	0.291	0.248	-
Shellfish	0.272	0.275	-	-	-	0.378	-
Whole grains	-	-	0.365	-	-	-	0.374
Refined grains	-	0.338	0.246	-	-	**0.425**	0.210
Potatoes	-	0.204	**0.417**	-	-	0.097	0.394
Soups and sauces	-	-	0.343	-	-	0.181	0.397
Savory snacks	-	**0.446**	-	-	-	**0.454**	-
Sweets	-	0.229	**0.441**	0.285	-	-	**0.521**
Soft drinks	-	0.286	-	-	-	0.288	0.237
Wine	0.246	0.233	-	-	0.246	-	−0.299
Other alcoholic drinks	-	-	-	-	-	**0.404**	-
Mineral water	0.303	-	-	-	0.289	0.100	-
Herb tea	0.299	−0.314	-	-	0.214	-	-
Black tea	-	-	0.209	-	-	−0.259	0.235
Coffee	-	0.338	-	-	-	0.328	-
Olive oil	-	-	**0.494**	-	-	-	0.266
Healthy fats	-	-	**0.619**	-	-	-	**0.532**
Unhealthy fats	-	-	**0.589**	-	-	-	**0.507**
Eigenvalues	3.051	2.302	1.753	1.588	3.140	2.326	1.776
Explained variance, %	8.973	6.770	5.155	4.671	9.236	6.842	5.223

The food groups presented, with factor loadings ≥0.2 or ≤−0.2, were considered to have an important association with at least 1 of the dietary patterns. Factor loadings >0.4 (bold) represent the highest and most explanatory for the specific pattern.
-, Weak associations.

a role through residual confounding. However, the effect was independent of UV exposure in our sensitivity analysis.

The main strength of our study is that we used 2 validated methods to capture dietary patterns associated with facial wrinkles in a large population-based cohort. Also, wrinkles were digitally quantified in a standardized and validated way, reducing interobserver bias and measurement error.

However, nutrition intake is difficult to capture accurately and our Food Frequency Questionnaire data correlates less with intake of vegetables and better with snacks in a validation study.[9] We tried to reduce confounding by adjusting for possible and known confounders in our analyses. Nonetheless, there are other possible residual confounders, which were not available in our data set, such as stress and hours of sleep per night. Another possible confounder is health-conscious behavior, as it is possible that people who eat healthy also tend to use sunscreen more often. Although our sensitivity analysis excluded confounding by UV protection behaviors, 45% of the data was missing, giving some uncertainty to the accuracy of this analysis. Finally, due to the cross-sectional design of our study, we cannot exclude reverse causality.

In conclusion, our findings imply that type of diet influences the severity of facial wrinkles in women, where an unhealthy diet significantly increases wrinkling and a healthy diet decreases facial wrinkling. This creates opportunities to stimulate adherence to a healthy dietary pattern in women who want to maintain a youthful appearance, which simultaneously could improve overall health and decrease mortality risk.[22]

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MATERIALS AND METHODS

Covariate selection

Sex and age were collected from the database. Education level, smoking habits, ultraviolet (UV) exposure and physical activity were retrieved from the interviews. Body mass index (BMI) was calculated from weight and height measured at the research center. Total energy intake per day in kilocalories was calculated using the Dutch Food Composition Table (NEVO) of 2006.[S1]

Food Frequency Questionnaire (FFQ)

The FFQ gives information on the consumption frequency and the average consumed amounts of 389 food items. The FFQ score was validated against dietary records over a 3-day period (4-5 months apart) in another Dutch population aged 55-69 years.[S2]

A priori food pattern

The DHDI is a composed measure of healthy nutritional behavior taking the Dutch governmental guidelines of a healthy diet into account, where a higher score correlates with the highest diet quality.[S3,S4] Physical activity and fish, fruit, vegetable, and fiber consumption are adequacy components, and saturated fatty acids, trans-fatty acids, number of consumption occasions of acidic drinks and foods, sodium, and alcohol are moderation components.[S4] In our study, we calculated the DHDI from the nutritional data out of the FFQ, leaving the physical activity component out, resulting in a healthiness grade 0-90.

A posteriori food patterns

The 389 food items were first subdivided into 34 food groups by a nutritionist (Supplemental Table I) on the basis of their nutritional characteristics and hypothesized association with skin aging.[S1] The principal component analysis (PCA) with varimax rotation extracted food patterns from the 34 food groups, explaining the maximum variation of food intake in women and men separately, since men and women tend to eat differently.[S5] Food patterns were considered relevant when showing an eigenvalue ≥1.5.

Statistical analysis

Associations between dietary intake and wrinkle area percentage were assessed using linear regression. Wrinkle area percentage was natural logarithm–transformed to normalize the distribution. For a more intuitive interpretation of the betas, we used the formula $(\exp^{\beta}-1) \times 100\%$, which results in a wrinkle percentage change. This is the percentage increase or decrease in wrinkle area per unit increase of the tested variable. All analyses were adjusted for technical variation, explained by 2 variables, which accounted for variations in resolution and flash light, as described in detail previously.[S6] We tested the association of the wrinkle percentage in both a basic model (adjusted for technical variation and age) and a multivariable model including all covariates (age, sex, BMI, daily energy intake, physical activity, smoking habit, education level). We tested for effect modification by BMI, which did not alter our results. All covariates had <8% missing data, which we replaced with multiple imputation. In our main analysis, we tested the association of DHDI (per 10 points increase in DHDI) and the relevant nutritional patterns from the PCA with wrinkle area adjusted for all covariates. The extra relevant food pattern in women was also tested in men. All analyses were conducted using IBM SPSS Statistics for Windows version 21.0.

UV variables

UV exposure variables included tanning bed use, hibernating in a sunny country, sunburn tendency, outdoor work, and UV protection behavior.

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Supplemental Table I. Single food group analysis in women

Food group	B	95% LB	95% UB	*P*
Citrus fruits	−0.022	−0.051	0.007	.14
All other fruits	−0.009	−0.021	0.003	.14
Total fruit*	−0.007	−0.017	0.002	.11
Green leafy vegetables	−0.028	−0.081	0.024	.29
Yellow vegetables†	−0.061	−0.112	−0.009	.02
All other vegetables	−0.005	−0.036	0.026	.76
Total vegetables*	−0.011	−0.028	0.006	.20
Pulses	0.048	−0.046	0.142	.32
Milk	0.008	−0.007	0.022	.29
Yogurt	0.015	−0.007	0.037	.19
Cheese‡	0.165	0.038	0.293	.01
Soy products†	−0.064	−0.119	−0.009	.02
Refined grains	−0.060	−0.129	0.010	.09
Whole grains	0.002	−0.038	0.042	.91
Soft drinks	0.002	−0.026	0.030	.87
Eggs‡	0.187	0.013	0.361	.04
Unprocessed meat	0.014	−0.091	0.118	.80
Processed meat	−0.114	−0.295	0.067	.22
Poultry†	−0.196	−0.382	−0.009	.04
Fatty fish	0.053	−0.110	0.216	.53
Lean fish	0.043	−0.143	0.230	.65
Shellfish	0.548	−0.137	1.238	.12
Total fish*	0.045	−0.056	0.147	.38
Savory snacks	0.115	−0.023	0.254	.10
Sweets	−0.048	−0.121	0.024	.19
Nuts and seeds	0.053	−0.156	0.262	.62
Coffee‡	0.016	0.003	0.029	.02
Black tea	−0.002	−0.016	0.012	.79
Herbal tea	−0.005	−0.026	0.017	.68
Mineral water	0.009	−0.002	0.019	.11
Alcoholic drinks other than wine	0.015	−0.018	0.048	.37
Wine‡	0.041	0.011	0.070	.01
Soups and sauces†	−0.048	−0.095	−0.002	.04
Potatoes	0.002	−0.048	0.053	.93
Olive oil	0.060	−0.467	0.589	.82
Healthy fats	0.015	−0.184	0.214	.88
Unhealthy fats‡	0.237	0.043	0.432	.02
Total fats*	0.103	−0.019	0.226	.10

Wrinkle percent change per 100 g intake of food group was calculated (N = 1613). Multivariable linear regression was adjusted for technical variation, age, body mass index, energy intake, physical activity, smoking, and education.

B, Beta; *LB*, lower bound; *UB*, upper bound.

*Because of their different nutritional characteristics, some of the food groups are presented both as a subgroup defined by a nutritionist (eg, citrus fruits that are high in vitamin C) and as a total together with all other fruits. Total fruits = citrus fruits + all other fruits. Total vegetables = green leafy vegetables + yellow vegetables + all other vegetables. Total fish = fatty fish + lean fish + shellfish. Total fats = olive oil + healthy fats + unhealthy fats.

†Significant association ($P < .05$) with less wrinkling.

‡Significant association ($P < .05$) with more wrinkling.