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Lifestyle and youthful looks*

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Conflicts of interest
Although no products were tested, it is possible that this manuscript could promote sales of anti-ageing regimens, which could lead to financial gain for Unilever, of which D.A.G., J.L.D., C.C.T., P.G.M. and A.E.M. are employees.

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Summary

Background Lifestyle has been proven to have a dramatic effect on the risk of age-related diseases. The association of lifestyle and facial ageing has been less well studied.
Objectives To identify lifestyle factors that associate with perceived facial age in white north European men and women.
Methods Lifestyle, facial wrinkling and perceived facial age were studied in two cross-sectional studies consisting of 318 Dutch men and 329 women aged 45–75 years who were part of the Leiden Longevity Study, and 162 English women aged 45–75 years who were nonsmokers.
Results In Dutch men, smoking, having skin that went red in the sun, being outside in the sun most of the summer, sunbed use, wearing false teeth and not flossing teeth were all significantly associated ($P < 0{\cdot}05$) with a total 9·3-year higher perceived facial age in a multivariate model adjusting for chronological age. In Dutch women, smoking, sunbathing, sunbed use, few remaining teeth and a low body mass index (BMI) were associated with a total 10·9-year higher perceived facial age. In English women, cleaning teeth only once a day, wearing false teeth, irregular skin moisturization and having skin that went red in the sun were associated with a total 9·1-year higher perceived facial age. Smoking and sunbed use were associated more strongly with wrinkling in women than in men. BMI, sun exposure and skincare were associated predominantly with perceived facial age via wrinkling, whereas oral care was associated via other facial features.
Conclusions Although associative in nature, these results support the notion that lifestyle factors can have long-term beneficial effects on youthful looks.

What's already known about this topic?

- Smoking, sun exposure and body mass index have been associated with the perceived age of subjects in passport-type images in a study of north Europeans aged ≥ 70 years.

What does this study add?

- Sunbed use and oral care were also found to associate significantly with a higher perceived facial age in 45–75-year-old north European men and women.
- Significant lifestyle factors accounted for around 10 years of perceived facial age, illustrating the strong relationship between lifestyle and perceived age.

One of the goals of ageing research is to provide interventions that can reduce the rate at which damage accumulates in the body and, hence, to help individuals maintain their health and vitality as they age. Heritability studies of the general population indicate that longevity[1] and many age-related diseases[2,3] are influenced predominately by environmental factors. Although stochastic influences are likely to account for some of this environmental influence,[4] lifestyle choices also play a significant role. For example, Khaw *et al.*[5] demonstrated that four lifestyle factors were additively associated with a fourfold lower mortality risk in a 14-year longitudinal study.

The lifestyles most commonly linked with aspects of skin ageing are smoking[6] and sun exposure.[7] Sun exposure is the main environmental exposure that does not directly affect internal organs in the body, although the production of vitamin D in skin from sun exposure can give indirect beneficial effects.[8] There is evidence that nutrition[9] and sleeping position[10] are linked with the presence and severity of skin wrinkling. However, it is unclear whether variation in normal sleeping patterns affects skin ageing over the long term, although there is evidence that short-term sleep deprivation affects facial appearance.[11]

Facial ageing consists of changes to many tissue types and is, to a degree, reflective of systemic ageing.[12] Indeed, some lifestyle factors that influence human longevity also associate with facial ageing. Rexbye *et al.*[13] found that smoking, sun exposure, being unmarried, belonging to a low social class and having a low body mass index (BMI) were significantly and independently (of each other and chronological age) associated with a higher perceived age. In addition, Mayes *et al.*[14] found that sun exposure, low socioeconomic status, exercising every day and poor skin and oral care were significantly and independently associated with a higher perceived facial age.

However, caution should be taken when comparing these studies due to notable differences in their methodology. Youthful looks can apply to many aspects of appearance, such as particular skin sites (e.g. crow's feet), images of the face (with or without eyes/mouth closed) or even videos of individuals walking and talking. Hence, particular attention to the subject matter is important, in order to understand what particular aspects of youthful looks a lifestyle is influencing. Indeed, Rexbye *et al.*[13] studied the perceived age of elderly (≥ 70 years) white Danish men and women in passport-type images, whereas Mayes *et al.*[14] studied the perceived facial age of Chinese women aged 25–70 years in facial photographs (i.e. not including hair and clothing cues). Hence, further studies are required to determine which lifestyle factors associate specifically with which ageing features presented for the perception of age.

We investigated the associations of self-reported sleep, alcohol intake, oral care, skincare, sun exposure, sunbed use and smoking with perceived facial age in a white Dutch male and female cohort, and in a white English female cohort. The same perceived facial age methodology and statistical approach were used for the English study as for the Dutch study, and without the influence of any findings from the Dutch cohort.

Patients and methods

The measurement of perceived facial age and skin wrinkling in both of the study cohorts, and their recruitment criteria have been reported in detail elsewhere.[15,16]

Study cohorts

In total, 337 women and 333 men were recruited from the Leiden Longevity Study (LLS).[17] There was no selection based on either health or demographic data. The study protocol was approved by the medical ethics committee of the Leiden University Medical Centre and participants gave written informed consent. English white women aged 45–75 years were recruited in southern England and gave written informed consent. The study was approved by the Unilever Colworth ethical committee. In total, 162 English women with perceived facial age data were available for analysis.[13]

Measurements

All participating assessors (Unilever employees based in England for perceived age, authors T.W.G., S.O. and C.E.M.G. for wrinkling grading) of the subjective measures were unaware of the subjects' ages and age ranges, and images were presented to them in a randomized order. The methodology used for generating perceived age from facial photographs has been reported in detail elsewhere,[18,19] and is also covered in Data S1 (see Supporting Information). Skin wrinkling grading of the facial images was carried out as previously reported.[15,16] In brief, a photonumeric scale[20] was used to grade each subject on a 1–9 scale by the number and depth of facial wrinkles. BMI was calculated by dividing weight (in kilograms) by height (in metres) squared; both variables were measured.

Questionnaires

To capture the environmental factors to which subjects had been exposed, detailed questionnaires were used in the Dutch and English studies. A number of lifestyle factors believed to influence facial ageing were selected from the lifestyle questionnaire; these were skincare, sun exposure, sunbed use, oral care, smoking, alcohol intake and sleep (Table S1; see Supporting Information), in addition to potential confounders such as education status and BMI. The questionnaires used in the Dutch and English studies were not identical but did contain mainly similar questions – a full list of questions examined in the analyses is provided in Table S1.

Data analyses

In total, 329 Dutch women, 318 Dutch men and 162 English women aged 45–75 years were available with perceived age data (Table 1). Lifestyle factors with evidence of association with perceived age in bivariate and LASSO (least absolute shrinkage and selection operator) models were taken forward

Table 1 Characteristics of the Dutch and English study cohorts

	Dutch women	Dutch men	English women
Number of participants	329	318	162
Chronological age (years)	61·6 (6·0)	63·8 (5·8)	59·5 (8·8)
Perceived age (years)	60·0 (7·9)	58·5 (6·8)	57·9 (9·5)
Wrinkle grading (grades 1–9)	4·6 (1·4)	4·6 (1·2)	5·3 (1·4)
Body mass index ($kg\ m^{-2}$)	26·4 (4·8)	26·9 (3·2)	Not available
Current smokers	33	42	0[a]

Values are n or mean (SE). [a]Selection criteria excluded smokers.

into a multivariate backward selection model to test for significant independent association with perceived age; chronological age was always retained in the model. Further details are provided in Data S1 (see Supporting Information).

The lifestyle variables identified from the backward selection model were next tested for their association with the wrinkle grading adjusting for chronological age, and also for perceived age adjusting for chronological age and wrinkle grading. For each effect, eta-squared was calculated, which is an indicator of the percentage variation accounted for by a variable in a model (Data S1; see Supporting Information).[21]

Facial averages/composites of women were created to visualize differences between individuals with contrasting lifestyles, based on the lifestyle factors that had significant association with perceived age (Table 2 and Data S1). Facial images were merged/averaged together as previously detailed using face shape, colour and texture information.[19,22]

Results

The characteristics of the Dutch male and female subjects and the English female subjects are presented in Table 1. The average ages were similar between the Dutch and English women, although there were no smokers in the English cohort due to recruitment criteria. There was a higher standard deviation of age ranges in the English cohort because recruitment targeted an even spread of subjects across the 45–75-year age range,[23] whereas the Dutch men and women were recruited as part of the LLS (offspring of 90-year-old siblings and the partners of the offspring),[17] meaning that there were fewer subjects at the ends of the age range.

Greater sun exposure and sunbed use, poorer oral care and smoking were all found to be significant ($P < 0·05$) predictors of a higher perceived facial age in the men and women in the LLS in a multivariate model (Table 2). In addition, a higher BMI was significantly associated with a lower perceived facial age in the women (those who were obese looked 2·1 years younger than those of normal weight, $P = 0·018$). No significant associations were found for questions on sleep or alcohol use. The average mean difference in perceived facial age between categorical responses within a lifestyle factor was between 1 and 3 years, and the total additive effects of the lifestyle factors within each model were 9·3 years in the men and 10·9 years in the women.

The types of questions within the oral and sun exposure categories that predicted perceived facial age were different between the men and women, but the direction of association was the same. In the men, flossing teeth (1·2 years younger, $P = 0·022$) and not wearing false teeth (1·4 years younger, $P = 0·012$) were significantly associated with a lower perceived facial age, whereas in women those with fewer than half of their teeth remaining looked older than those with most of their teeth remaining (2·3 years older, $P = 0·003$). The sunbathing habits of women were significantly associated with perceived facial age (those who said they often sit in the sun looked 2·5 years older than those who do not go into the sun, $P = 0·013$). For men, being outside in the sun during the summer (those outside most of the time looked 1·7 years older than those not outside as much, $P = 0·046$) and skin type (those whose skin went red when first exposed to the sun after winter looked 2 years older than those whose skin tanned easily, $P = 0·003$) were associated with perceived facial age.

In an independent analysis in the English cohort, the following were all significant independent predictors of a higher perceived facial age in a multivariate model (Table 3): skin reaction (those who said their skin went red in the sun looked 2·8 years older than those who said their skin tanned easily, $P = 0·01$); poorer oral care (those who brushed their teeth once a day or less looked 1·9 years older than those who brushed twice or more a day, $P = 0·038$; those who wore false teeth looked 2·5 years older than those who did not, $P = 0·003$); and poorer skincare (those who moisturized irregularly looked 1·9 years older than those who moisturized regularly all their life, $P = 0·023$). BMI data were unavailable for this cohort. The total perceived age difference between those with the optimal responses (i.e. good oral and skincare, darker skin type) and those with the least optimal was 9·1 years.

Next, we assessed each lifestyle factor that was a significant predictor of perceived facial age for its association with wrinkling and perceived facial age after adjusting for the wrinkle grading. This removes the influence of wrinkles on perceived facial age, leaving features that affect face shape, such as sagging, predominately responsible for the remaining perceived age variation; this is herein referred to as face shape, for simplicity. Less sun exposure, more regular skin moisturization and a higher BMI were associated predominately with less wrinkling, whereas good oral care (except for the question on false teeth/dentures) was more strongly associated with fewer face shape changes (i.e. the adjusted perceived age) (Table 4). As an increased BMI could be interpreted as a positive aspect for youthful looks, we noted that a high BMI was associated with greater face shape changes in women and men (Table S2; see Supporting Information), albeit only significantly in the men. Smoking and sunbed use were more strongly associated with a higher wrinkle grade in the Dutch women than in the Dutch men.

Table 2 Significant associations of lifestyle factors with perceived age in Dutch men and women

	Dutch men			Dutch women		
Lifestyle factors and response categories	Mean perceived age (years)[a]	Greatest difference (years)	P-value	Mean perceived age (years)[a]	Greatest difference (years)	P-value
Do you smoke?						
Yes	60·3 (0·71)	1·6	0·023	62·5 (0·94)	2·3	0·013
No	58·7 (0·38)			60·2 (0·47)		
Body mass index group						
Normal weight			NS	62·5 (0·65)	2·1	0·018
Overweight				61·3 (0·92)		
Obese				60·4 (0·65)		
Do you floss your teeth?						
Yes	58·9 (0·54)	1·2	0·022			NS
No	60·1 (0·49)					
Do you wear false teeth?						
Yes	60·2 (0·55)	1·4	0·012			NS
No	58·8 (0·50)					
Number of teeth?						
Fewer than half			NS	62·7 (0·74)	2·3	0·003
More than half				61·6 (0·87)		
Most				60·4 (0·71)		
All				60·8 (0·89)		
How many times a year do you use a sunbed?						
≥ 6	NA			62·3 (0·87)	1·7	0·044
1–5	NA			61·3 (0·89)		
≥ 1	60·2 (0·65)	1·4	0·032	NA		
Never	58·8 (0·42)			60·6 (0·56)		
How does your skin react to the sun?						
Goes red	60·6 (0·56)	2·0	0·003			NS
Goes pink	59·4 (0·56)					
Tans easily	58·6 (0·60)					
How often have you been in the sun in the summer?						
Outside most of the time	60·3 (0·63)	1·7	0·046			NS
Outside often	59·6 (0·46)					
Not outside much	58·6 (0·71)					
What do you do when sunbathing?						
Often sit in the sun				63·0 (0·80)	2·5	0·013
Sometimes sit in the sun				60·6 (0·60)		
Don't sit in the sun				60·5 (0·89)		
Total difference in perceived age (years)		9·3			10·9	

NA, not available; NS, not significant. [a]Data are mean perceived ages in the multivariate models (SE).

Finally, composite images of 12 women who had fewer than half of their teeth remaining, liked to sunbathe often in the sun and also used a sunbed had visibly greater skin wrinkling (most notable in the lower half of the face), less lip height and a darker skin colour than 12 women who had most of their teeth left and did not like to sunbathe or use a sunbed (Fig. 1).

Discussion

Here, we find significant evidence for association of sun exposure, sunbed use, smoking, oral care, skincare and BMI with perceived facial age in two white populations. These associations were independent of each other and together could predict up to 11 years of difference in perceived age. Lifestyles of particular note were sun exposure and oral care, as they were significantly associated with perceived age in both sexes and both populations, and in the same direction (greater sun exposure and poor oral care result in looking older). These studies are the first to link oral care and sunbed use with perceived age in a white population, and to examine whether facial wrinkling is predominantly responsible or not for the links between lifestyle and perceived age.

Wrinkling has been noted for many years to be more prevalent in sun-exposed body sites than sun-protected sites,[7] sunscreens have been demonstrated to prevent the appearance of wrinkling,[24] and ultraviolet (UV) radiation causes a wide range of cellular damage, particularly to DNA.[18] In support of this, we found that sunbathing habits and sunbed use were strongly associated with increased wrinkling in women. In

Table 3 Significant associations of lifestyle factors with perceived age in English women

Lifestyle factors and response categories	Perceived age mean (years)[a]	Greatest difference (years)	P-value
How often do you clean your teeth?			
Once a day	59·6 (0·85)	1·9	0·038
Twice or more a day	57·7 (0·50)		
Do you wear false teeth?			
Yes	59·9 (0·79)	2·5	0·003
No	57·4 (0·55)		
How does your skin react to the sun?			
Goes red	59·8 (0·61)	2·8	0·010
Goes pink	59·2 (0·66)		
Tans easily	57·0 (0·99)		
How often have you moisturized your skin?			
Irregularly	59·9 (0·76)	1·9	0·023
Regularly last few years	58·2 (0·79)		
Regularly all my life	58·0 (0·66)		
Total difference in perceived age		9·1	

[a]Data are mean perceived ages in the multivariate model (SE).

Fig 1. Composite/average images of 12 women with (a) an optimal lifestyle and (b) a suboptimal lifestyle. Individuals were selected on sunbed use, number of teeth and sunbathing habits. There are visible differences in skin colour, lip size, sag and wrinkling, particularly in the lower half of the face. The average chronological age of the optimal lifestyle group was 63 years, with an average body mass index (BMI) of 25 kg m^{-2}; the suboptimal group was aged 61 years on average and had an average BMI of 26 kg m^{-2}.

men, being outside in the sun during the summer was associated predominately with wrinkling, and sunbed use was equally associated with increased wrinkling and face shape changes. Hence, the use of sunbeds or sunbathing for beauty purposes (a tanned appearance is associated with attractiveness in white populations)[19] in the short term is actually likely to be counterproductive in the long term.

How skin responds to sun exposure after the winter is due mainly to genetic differences,[25] with those who say their skin goes red (after exposure to an hour's sun after the winter) being more prone to sun-induced premature skin ageing. Indeed, Dutch men and English women who reported that their skin goes red in the sun looked older than those who said their skin tans. However, no significant association was found in the Dutch women, and skin type was strongly associated with face shape changes in the men, whereas it was more strongly associated with wrinkling in the English women. Hence, the exact role that skin type plays in the development of facial ageing features is unclear, possibly in part as the skin type question responses were also likely indicative of sun exposure behaviour (e.g. those whose skin goes red in the sun could be more likely to avoid sun exposure than those whose skin tans). More accurate measurements of skin type and sun

Table 4 Eta-squared values for associations between lifestyle variables and facial wrinkling and perceived age adjusted for facial wrinkling (i.e. targeting face shape changes)

	Dutch men		Dutch women		English women	
Lifestyle factor	Wrinkles	Face shape	Wrinkles	Face shape	Wrinkles	Face shape
Body mass index group			2·16[a]	0·35	NA	NA
Do you smoke currently?	0·17	0·54[a]	1·87[a]	0·19	NA	NA
Do you wear false teeth?	0·55	0·37			0·57	0·56
Do you still have teeth?			0·02	2·88[a]		
How often do you clean your teeth?					0·01	1·14[a]
Do you floss your teeth?	0·01	2·39[a]				
What you usually do when sunbathing			2·77[a]	0·21	NA	NA
How often in the sun in the summer?	1·48[a]	0·74				
How often do you use a sunbed?	0·36	0·34	1·49[a]	0·38	NA	NA
Skin reaction to 1 h in the sun	0·12	1·34[a]			1·97[a]	0·57
Moisturizer use over life	NA	NA			0·62[a]	0·14

NA, not available. The numbers are a conservative estimation of perceived age variation explained in a multivariate model and are analogous to the square of a correlation (R^2). [a]Variables with a greater than twofold increase in the eta-squared values between the wrinkles and face shape models.

exposure are now required to dissect their influences on facial ageing features.

Smoking is strongly linked to skin ageing features independently of potential confounders such as sun exposure,[22,26] BMI[26] and social economic status,[27] and smokers have greater skin elastosis,[28] lower levels of skin oxygenation[29] and reduced collagen, but enhanced collagenase production response *in vivo* to UV radiation.[30] Here, smoking was significantly associated with perceived facial age in Dutch women and men, but was more strongly associated with wrinkling in the women, compared with face shape changes in the men. Evidence for differences between sexes for smoking effects is limited, although one previous study found that female but not male smokers had more wrinkles than nonsmokers.[26] Overall, this study supports the overwhelming evidence that smoking is a driver of skin ageing, but further study is required to determine whether there are sex differences in the effects of smoking on the skin.

A higher BMI was previously found to be significantly associated with a lower perceived age[13] and reduced wrinkling.[26] We found the same association in women; a similar trend was found in the men, but this was not statistically significant (data not shown). BMI was also more strongly associated with wrinkling than face shape changes in the women. Increased facial fat could reduce the appearance of wrinkles by expanding the skin outwards in a similar manner to facial fillers. Hence, although obesity has a negative impact on ageing systemically, in the face this effect is likely masked (at least in middle-aged to elderly populations)[31] by the reduction in skin wrinkling. Indeed, we found evidence that once the wrinkling grading was adjusted for, a higher BMI was associated with a higher perceived facial age (Table S2; see Supporting Information). In support of this, facial sagging is linked to increased subcutaneous fat in the face,[32] and mice fed on a high-fat diet had increased skin elasticity and reduced dermal thickness.[33] Thus, although an increased BMI could help reduce the appearance of wrinkles it could well lead to premature facial sagging.

Although the subjects had their mouths closed, aspects of oral care were significantly associated with perceived facial age in all groups studied, and were also associated with perceived facial age in a Chinese cohort[14] using an identical perceived age methodology. A causal link between oral care and perceived age cannot be determined from this study and, thus, it is possible that the oral care questions were just proxies of other lifestyle factors (e.g. diet). However, the number of teeth and the condition of the surrounding gums are known to have a direct influence on the appearance of overlying tissues. For example, people look younger with their mouths closed after receiving new dentures than before,[34] and the number of teeth or the use of dentures has been linked to lip size and the appearance of the labiomental fold.[35,36] Hence we postulate that the oral care questions, irrespective of the question specifics, were proxies of the overall condition of the mouth, which, through its support to the overlying tissues and their subsequent appearance, can influence perceived facial age.

There is currently little evidence that variation of alcohol consumption within recommended intake levels affects skin ageing,[37,38] and we could find no association between self-reported alcohol intake levels and perceived facial age. We also found little evidence for any association between sleep length or quality and perceived facial age, in contrast to studies showing how acute sleep deprivation can influence facial appearance.[11,39] This could be due to the fact that self-report is not a good indicator of actual sleep length and quality (or alcohol intake), or that long-term differences in sleep length and quality have only a small impact on facial appearance. Larger studies with more accurate measures of alcohol intake and sleep are now required to determine whether they influence facial ageing.

Regular skin moisturization was significantly associated with a lower perceived facial age in the English but not the Dutch cohort. There is some evidence that skin moisturization is capable of directly influencing skin ageing. For example, it has been shown to improve skin hydration and condition,[40,41] to reduce the presence of inflammation markers[40] and, in a Chinese study, to associate with lower perceived facial age.[14] However, as self-reported moisturizer use did not significantly associate with perceived facial age in the larger Dutch cohort, and the studies were cross-sectional, the causal nature of moisturizer use with skin ageing cannot be determined. Other limitations to the studies here include the reliance on self-report for lifestyle exposures (e.g. frequency of teeth cleaning captured current rather than historical habits) and the fact the Dutch subjects consisted partly of individuals from long-lived families. However, the families are long lived due to genetic and early-life experiences, rather than their adult lifestyle,[42] and similar perceived age differences were found within the controls as per the whole cohort (data not shown), suggesting that similar results should be found in other Dutch cohorts, although replication is warranted. Although the lifestyle factors were additive within the multivariate model, we lacked the statistical power to detect interactions between the lifestyles (e.g. sun avoidance ameliorates the effects of smoking), and larger studies are required to detect such interactions.

Chauhan *et al.*[43] demonstrated that cosmetic surgery can reduce an individual's perceived age by up to 8 years. Here, we find up to 11 years' difference between those who report an 'optimal' lifestyle and those with the least 'optimal' lifestyle. This indicates that lifestyle could have a larger influence on youthful looks than cosmetic surgery. Although caution is warranted due to the associative nature of the relationships found, these data support the notion that lifestyle can have a large impact on the preservation of youthful looks and could be a motivating message for some to adopt a more healthy lifestyle.

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Supporting Information

Additional Supporting Information may be found in the online version of this article at the publisher's website:

Data S1. Additional methods and results.

Table S1. Questions used in the statistical analyses and evidence for association with perceived facial age in a bivariate model and in the LASSO procedure.

Table S2. Lifestyle factors that significantly associated with perceived age after adjusting for chronological age and facial wrinkling in the Dutch cohort.