The epidemiology of acne vulgaris in a multiethnic adolescent population from Rotterdam, the Netherlands: A cross-sectional study

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Background: Although acne is a prevalent multifactorial inflammatory skin condition, few studies were performed in multiethnic populations.

Objectives: To study the prevalence and determinants of acne in a multiethnic study at the start of puberty.

Methods: This cross-sectional study is embedded in Generation R, a population-based prospective study from Rotterdam, the Netherlands. Three-dimensional facial photos at the center visit in 2016-2019 (of ~13-year-olds) were used to grade acne severity using the Global Evaluation of the Acne Severity (GEA). Analyses were stratified by biological sex and explored through chi-square tests and multivariable ordinal logistic regression.

Results: A total of 4561 children (51% girls) with a median age of 13.5 (IQR 13.3-13.6) were included. The visible acne prevalence (GEA 2-5) for girls vs boys was 62% vs 45% and moderate-to-severe acne (GEA 3-5) 14% vs 9%. Higher puberty stages (adjusted odds ratios: 1.38 [1.20-1.59] and 2.16 [1.86-2.51] for girls and boys, respectively) and darker skin colors V and VI (adjusted odds ratios: 1.90 [1.17-3.08] and 2.43 [1.67-3.56]) were associated with more severe acne in both sexes, and being overweight in boys (adjusted odds ratio: 1.58 [1.15-2.17]).

Limitations: Cross-sectional design.

Conclusions: Acne prevalence was high at the age of 13 years and was associated with advanced puberty, darker skin color, and weight status. (J Am Acad Dermatol 2024;90:552-60.)

Key words: acne vulgaris; clinical research; epidemiology; ethnicity; family medicine; general dermatology; medical dermatology; multiethnic; pediatrics; skin color.

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INTRODUCTION

Acne is an inflammatory condition of the pilosebaceous unit with a prevalence estimated to be up to 95%[1] depending on the population studied and the definition of acne used.[2] Clinically, acne is characterized by comedones, papules, pustules, and nodules and can result in postinflammatory hyperpigmentation and scarring.[3] Typically, acne begins at the onset of puberty. Although acne usually remits after puberty, approximately 40% of adults aged between 30 and 39 years are still affected.[4] Acne has been ranked second among the skin diseases according to the Global Burden of Disease study[5,6] owing to the high prevalence and a psychological burden at a sensitive age. Psychological symptoms that have been associated with acne include depression, withdrawal, stress, isolation, and even suicide.[7,8]

CAPSULE SUMMARY

- More than half of the 13-year-olds already have acne vulgaris, with girls more commonly affected than boys and 11% having moderate-to-severe acne.
- Identification of having a darker skin color as a determinant for more severe acne can aid in earlier detection, management, and prevention.

The pathophysiology of the disease is a combination of an increased sebum production because of rising levels of androgens during puberty and hyperkeratinization of the follicular duct. Furthermore, proliferation of the skin commensal *Cutibacterium acnes* as a consequence of the lipid-rich anaerobic environment and a local inflammatory reaction contribute to acne. The exact order of these events remains unclear.[3]

Several risk factors have been associated with acne severity, such as being overweight[1] and having a more advanced puberty stage.[9,10] However, sex, socioeconomic status and skin color have been inconsistently associated with acne severity.[1] Additionally, lifestyle factors such as physical activity levels and dietary habits have shown inconsistent results.[1,11,12] Moreover, there is a lack of studies assessing acne in multiethnic population-based settings.

The aims of our study are to estimate the acne severity in a multiethnic adolescent population-based study and to investigate associations with main demographic and host's factors.

METHODS

Data set

We performed a cross-sectional study within the Generation R cohort. Generation R is a population-based prospective study based in Rotterdam, the Netherlands that started in 2002 and is still ongoing. The study enrolled children and their parents from the prenatal period until adulthood with the aim of identifying early genetic and environmental causes of health and its relationship with diseases later in life.[13] We focused at the age category of 13 years("Focus@13") in which adolescents and their parents visited the research center and completed questionnaires.

Acne phenotyping

As part of the follow-up measurements, three-dimensional photos of the frontal and lateral aspects of the face, taken in standardized conditions were available. Two trained physicians (WW and LP) independently scored the photos using the Global Evaluation of the Acne Severity score (GEA) (Supplementary Table I, available via Mendeley at https://data.mendeley.com/datasets/zjddtdsbjn/1).[14] In the case of unsolved discordance, an independent dermatologist (ER) decided on a final score or exclusion due to either an underlying disease or insufficient quality of the photo (Fig 1).

Based on the distribution of the GEA scores in the population 3 ordinal categories were created: (almost) clear (GEA 0-1), mild (GEA 2), and moderate-to-severe (GEA 3-5). Visible acne prevalence was defined as GEA 2 to 5.

Determinants

The perceived skin color was also assessed using the photos by the 2 trained physicians and subdivided into 3 categories: skin color I and II, III and IV, and V and VI using a clinical grade previously validated.[15] Other variables investigated in this study were: social economic status, Cole weight status, Tanner puberty stages, physical activity frequency, mental well-being, and ethnicity. Age was excluded from the model because 98% of participants were 13 years old. Socioeconomic status was measured using maternal education, namely, low (no or primary education), intermediate (secondary school, vocational training), and high (bachelor's degree, university).

During the child's visit, the body mass index (BMI) was measured and the Cole weight status[16] was used to calculate BMI standardized by age and sex. This was categorized as underweight (thinness grade 1-3), normal weight (normal weight), and overweight (overweight and obese). The puberty

Abbreviations used:

BMI: body mass index
GEA: Global Evaluation of the Acne Severity score
OR: odds ratio

stage was measured using the self-reported 5-point validated Tanner stages.[17,18] The psychological symptoms of the adolescents were assessed by the validated Youth Self-Report.[19] In this study we focused on the internalizing (ie, anxious/depressed, depressed/withdrawn, and somatic complaints) and externalizing problems (ie, rule-breaking and aggressive behavior).[19] The scales are displayed as sum scores in the demographics, but were square root transformed and standardized as *z*-scores in the further analysis. Physical activity was assessed as follows: "How many days do you usually perform physical activity in a way that gets you out of breath?" resulting in 3 categories: "(almost) daily" (>4 a week), "weekly" (<3 times a week), and "monthly/never" (<once per month). Ethnicity was categorized according to the official definition of the Dutch Central Bureau of Statistics.[20] Because this variable is predominantly culturally defined and is a proxy for dietary habits and lifestyle, it was only explored separately in relation to acne severity and in the sensitivity analysis to adjust for skin color, but was not included in the main model.

Statistical analysis

IBM SPSS version 28.0.1.0 (142) and R version 4.2.1 were used for all analyses. The inter- and intraobserver intraclass correlation coefficient was calculated using a 2-way mixed model to test for the absolute agreement for single and average measures. First, categorical covariates were analyzed separately in relation to the acne severity categories using complete cases and chi-square tests. Then, owing to the sex-specific Tanner definitions sex stratified analyses were conducted. Missing data in covariates were imputed assuming missingness at random. Missing values ranged from 0% to 34.6%. Multiple imputation was done using chained equations with the Markov Chain method[21] in which 30 data sets with 50 iterations were created (Supplementary Tables II and III, available via Mendeley at https://data.mendeley.com/datasets/zjddtdsbjn/1). Finally, multivariable ordinal logistic regression models were used to estimate the pooled effect sizes between covariates and acne severity. These models satisfied all assumptions (including the proportional odds assumption) resulting in adjusted odds ratios (ORs) and 95% confidence intervals.

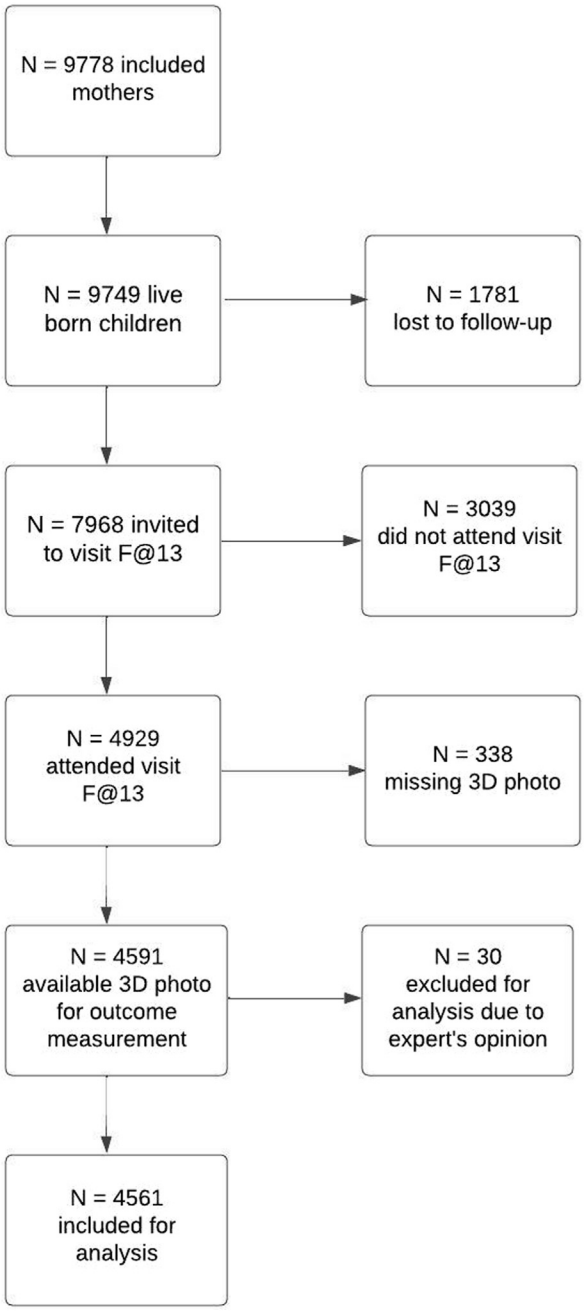

Fig 1. Flowchart depicting participant's inclusions.

RESULTS

Demographics study population

Out of the 9749 participants who were initially enrolled in the Generation R study, 4929 visited the research center in this follow-up, of whom 4561 were eligible for analysis (Fig 1). Adolescents who were excluded differed compared with those included (Supplementary Table IV, available via Mendeley at https://data.mendeley.com/datasets/zjddtdsbjn/1).

Table I. Demographics of the study population stratified by biological sex

Demographics	Boys (*n* = 2235)	Girls (*n* = 2325)	*P* value
Maternal characteristics			
Age at enrollment (y), mean (SD)	31.2 (5.0)	31.0 (5.0)	.3
Maternal education*			
Low	3.2 (61)	2.9 (57)	.8
Intermediate	36.2 (697)	36.0 (718)	
High	60.7 (1170)	61.1 (1219)	
Child characteristics			
Age (y), median (IQR)	13.6 (13.4-13.7)	13.5 (13.4-13.7)	.2
Tanner (genital/breast [M] development)*			
G1/M1	1.8 (25)	1.0 (19)	NA
G2/M2	15.8 (217)	11.6 (217)	
G3/M3	41.1 (565)	40.4 (753)	
G4/M4	34.2 (470)	39.0 (728)	
G5/M5	7.2 (99)	7.9 (148)	
Tanner (pubic hair)*			
PH1	4.6 (73)	1.4 (23)	NA
PH2	18.6 (295)	9.1 (153)	
PH3	35.1 (557)	27.4 (463)	
PH4	35.6 (565)	42.0 (710)	
PH5	6.2 (99)	20.1 (340)	
Ethnicity*			.4
Dutch	61.8 (1356)	62.3 (1414)	
Moroccan	5.0 (109)	5.4 (122)	
Surinamese	7.2 (159)	6.1 (139)	
Turkish	5.1 (113)	4.8 (109)	
European	7.1 (156)	8.4 (190)	
Other†	13.8 (302)	13.1 (297)	
Visual perceived skin color			.8
I and II	61.6 (1377)	61.0 (1408)	
III and IV	28.6 (640)	29.0 (684)	
V and VI	9.8 (218)	10.0 (233)	
Cole weight status			.14
Underweight	10.6 (237)	10.4 (241)	
Normal weight	74.1 (1657)	72.2 (1679)	
Overweight	15.3 (341)	17.4 (405)	
GEA severity status			<.01‡
(Almost) clear	55.2 (1233)	37.9 (882)	
Mild	36.1 (807)	48.3 (1123)	
Moderate-severe	8.7 (195)	13.8 (320)	
Internalizing psychological symptoms§, median (IQR)*	6.0 (3.0-10.0)	9.0 (5.0-14.0)	<.01‡
Externalizing psychological symptoms§, median (IQR)*	6.6 (4.0-10.0)	5.2 (3.0-9.0)	<.01‡
Physical activity frequency*			<.01‡
(Almost) daily	35.7 (505)	29.2 (463)	
Weekly	49.2 (695)	53.9 (855)	
Monthly/never	15.1 (213)	16.8 (267)	

Values are valid percentages (absolute values), mean (SD), or median (interquartile range) based on observed data.
Independent *t* tests and Mann-Whitney U tests were used for continuous variables and chi-square tests were used for categorical variables.
NA, Not applicable.
*Data were missing, and analysis was based on complete cases.
†Asian, Oceanian, Dutch Antilles, Cape Verdian, American, and African.
‡Statistically significant.
§Youth Self-Report scores are displayed as sum scores.

Table II. Relation of categorical variables and acne severity*

Child characteristic	(Almost) clear	Mild	Moderate-to-severe	*P* value
Biological sex				<.01†
Female	37.9 (882)†	48.3 (1123)†	13.8 (320)†	
Male	55.2 (1233)†	36.1 (807)†	8.7 (195)†	
Maternal education‡				<.01†
Low	41.5 (49)	47.5 (56)	11.0 (13)	
Intermediate	42.8 (605)†	44.3 (627)†	12.9 (183)†	
High	50.3 (1202)†	40.2 (960)†	9.5 (227)†	
Visual perceived skin color				<.01†
I and II	51.0 (1420)†	39.2 (1091)†	9.8 (274)†	
III and IV	44.5 (589)	45.6 (604)	10.0 (132)	
V and VI	23.5 (106)†	52.3 (236)†	24.2 (109)†	
Cole weight status				<.01†
Underweight	63.2 (302)†	30.5 (146)†	6.3 (30)†	
Normal weight	46.7 (1559)	42.4 (1415)	10.9 (362)	
Overweight	34.0 (254)†	49.5 (369)†	16.5 (123)†	
Physical activity‡				<.01†
(Almost) daily	36.3 (523)†	28.7 (361)†	27.7 (84)	
Weekly	49.9 (718)	52.9 (665)	55.1 (167)	
Monthly/never	13.8 (198)†	18.3 (230)†	17.2 (52)	

Values are percentages (absolute values) based on observed data. Chi-square tests and Fisher's exact tests were used for categorical variables.

*Ethnicity was excluded of the analysis because of the subjective definition and visual perceived skin color was used instead.

†Statistically significant.

‡Data were missing, and analysis was based on complete cases.

Table I shows the characteristics of the adolescents (51% girls at median age of 13.5 years) and their mothers stratified by sex. The median age, ethnicity, perceived skin color, and Cole weight status were all comparable across both sexes. Sixty-two percent of the children had a Dutch ethnicity and the 4 largest non-Dutch groups were: European, Surinamese, Moroccan, and Turkish. Sixty-one percent of participants had skin colors I to II and 10% had skin colors V to VI. Between 15% and 17% of the children were overweight. Most boys had genital Tanner stage G3 (41.1%) and pubic hair Tanner stage PH4 (35.6%) and most girls had breast development Tanner stage M3 (40.4%) and pubic hair Tanner stage PH4 (42.0%). Girls had a higher weighted sum score than boys on the internalizing symptom scale (girls vs boys: 9.0 vs 6.0, $P < .01$), whereas this was the other way around for the externalizing symptom scale (girls vs boys: 5.2 vs 6.6, $P < .01$). Boys performed physical activity more frequently than girls (36% vs 29% reported daily activities, $P < .01$).

Acne severity prevalence and determinants

The intraclass correlation based on 1000 pictures was 0.89 (95% CI, 0.80-0.93, $P < .01$) for all cases and 0.80 (95% CI, 0.67-0.87, $P < .01$) for individual cases between the 2 independent physicians. The interclass correlation was calculated 6 months later based on 100 pictures and was 0.86 (95% CI, 0.85-0.88, $P < .01$) for all cases and 0.76 (95% CI, 0.73-0.79, $P < .01$) for individual cases. This result was comparable to previous literature.[14]

The visible acne prevalence was 54% considering both sexes. Girls had a worse acne severity profile than boys ($P < .01$) with a visible acne prevalence of 62% compared with 45%. In addition, 14% of the girls had moderate-to-severe acne compared with 9% of the boys (Table II). An overview of the total GEA scores can be found in Supplementary Fig 1 (available via Mendeley at https://data.mendeley.com/datasets/zjddtdsbjn/1).

Adolescents with darker skin had moderate-to-severe acne more often compared with those with skin colors I to II (24.2% vs 9.8%; $P < .01$) (Table II). Darker skin remained significantly associated with acne severity in the multivariable model (adjusted ORs: 1.90 [95% CI, 1.17-3.08] and 2.43 [1.67-3.56]) for girls and boys (Tables III and IV). Adolescents who were more advanced in puberty, had more severe acne. The Tanner (PH) had a slightly lower OR of 1.38 (1.20-1.59) in girls compared with 2.16 (1.86-2.51) in boys. Another determinant for moderate-to-severe acne was being overweight compared with being normal weight or underweight (prevalence of

Table III. Associations of child characteristics with acne severity category in girls

Characteristic	β (multivariable)	SE	Adjusted OR (95% CI)
Tanner (breast development)	0.21	0.08	1.23 (1.05-1.44)*
Tanner (pubic hair)	0.32	0.07	1.38 (1.20-1.59)*
Skin color I and II (reference)			
III and IV	0.07	0.14	1.07 (0.82-1.41)
V and VI	0.64	0.25	1.90 (1.17-3.08)*
Maternal education: low (reference)			
Intermediate	0.23	0.30	1.26 (0.70-2.25)
High	−0.001	0.30	1.00 (0.56-1.79)
Cole weight status: normal (reference)			
Underweight	−0.48	0.19	0.62 (0.43-0.90)*
Overweight	0.26	0.17	1.30 (0.93-1.82)
Internalizing problems	0.03	0.07	1.03 (0.90-1.17)
Externalizing problems	−0.02	0.07	0.98 (0.86-1.12)
Physical exercise: monthly/never (reference)			
Weekly	0.01	0.16	1.01 (0.73-1.39)
(Almost) daily	−0.18	0.18	0.98 (0.58-1.19)

The β, SE, and adjusted odds ratio are the results of the ordinal logistic multivariable analyses, with all of the above variables included. The outcome acne severity ranges from least to most severe acne: (1) (almost) clear, (2) mild, or (3) moderate-to-severe. Analyses are based on the imputed data set and are the pooled result of 30 data sets with 50 iterations. ORs marked with asterisk are statistically significant.

Table IV. Associations of child characteristics with acne severity category in boys

Characteristic	β (multivariable)	SE	Adjusted OR (95% CI)
Tanner (genital development)	0.25	0.08	1.29 (1.11-1.49)*
Tanner (pubic hair)	0.77	0.08	2.16 (1.86-2.51)*
Skin color: I and II (reference)			
III and IV	−0.18	0.14	0.84 (0.64-1.10)
V and VI	0.89	0.19	2.43 (1.67-3.56)*
Maternal education: low (reference)			
Intermediate	0.14	0.25	1.15 (0.70-1.89)
High	0.19	0.26	1.21 (0.73-2.00)
Cole weight status: normal (reference)			
Underweight	−0.28	0.20	0.76 (0.52-1.11)
Overweight	0.46	0.16	1.58 (1.15-2.17)*
Internalizing problems	−0.02	0.07	0.98 (0.86-1.12)
Externalizing problems	−0.04	0.07	0.97 (0.84-1.10)
Physical exercise: monthly/never (reference)			
Weekly	−0.14	0.18	0.87 (0.61-1.23)
(Almost) daily	−0.40	0.20	0.67 (0.46-0.99)*

The β, SE, and adjusted odds ratio are the results of the ordinal logistic multivariable analyses, with all of the above variables included. The outcome acne severity ranges from least to most severe acne: (1) (almost) clear, (2) mild, or (3) moderate-to-severe. Analyses are based on the imputed data set and are the pooled result of 30 data sets with 50 iterations. ORs marked with asterisk are statistically significant.

respectively 16.5%, 10.9%, and 6.3%, $P < .01$), which remained significant in the multivariable model, for boys (adjusted OR: 1.58 [1.15-2.17]), but not for girls. Additionally, boys who exercised more, had a lower odds of more severe acne (adjusted OR: 0.67 [0.46-0.99]), but there was no association in girls (adjusted OR: 0.98 [0.58−1.19]) for daily exercise (reference: monthly/never).

Adolescents with mothers who had a high education had less severe acne ($P < .01$), but this negative association disappeared in the multivariable model. Finally, the internalizing and externalizing symptoms were not significantly associated with acne severity in both sexes.

Sensitivity analyses

Supplementary Tables II and III show that the findings of the imputed data sets were comparable to the complete cases data sets. Supplementary Tables V and VI (available via Mendeley at https://data.

mendeley.com/datasets/zjddtdsbjn/1) present the results of the multivariable analysis with ethnicity included and show that the effect of other determinants remained unchanged. In Supplementary Table VII (available via Mendeley at https://data.mendeley.com/datasets/zjddtdsbjn/1) the prevalence of children with different skin colors across their ethnicities were explored and showed a large mix of skin colors per ethnicity group.

Supplementary Fig 2 (available via Mendeley at https://data.mendeley.com/datasets/zjddtdsbjn/1) displays a separate sensitivity analysis with the relation of Tanner (PH) stage and sex and shows a higher percentage of boys with Tanner (PH) stages 1 to 3, whereas a higher percentage of girls have Tanner (PH) stages 4 to 5.

DISCUSSION

In this study we found that 54% children starting puberty had visible acne, with girls having a higher visible prevalence of acne than boys of the same age (62% and 45%, respectively). Moderate-to-severe acne occurred in 9% of boys and 14% of the girls. The more severe acne in girls compared with boys at this age is most likely due to an earlier start of puberty in girls,[1,17,18,22,23] which we confirmed in our sensitivity analysis. It is difficult to compare our prevalence numbers to other literature because of various acne definitions (with different thresholds), research methodology, and sample size. Global acne prevalence estimates in this age category range from 45% to 96%, with a relatively higher prevalence in girls.[24-28] Several studies have reported a higher prevalence in boys as they advance puberty,[4,24,25,29] but a recent systematic review calculated a pooled OR of 1.07 (95% CI, 0.42-2.71) for males compared with females indicating no discernible risk difference between the sexes.[1]

One of the most interesting findings of this study is the positive association between having a darker skin color and having more severe acne. Adolescents with skin colors V to VI had an odds of 1.90 to 2.43 to have more severe acne in comparison to those with lighter skin colors even after adjusting for Tanner stage and BMI. Perkins et al[30] already reported a higher acne prevalence in African American women of all age groups (skin color Fitzpatrick IV-VI) compared with other ethnicities, but reported nothing on acne severity specifically. Several hypotheses could explain this finding. Ethnic differences in determinants for acne have been described before such as earlier puberty in children with darker skin compared with light skin[10,31] and higher BMI in non-Europeans[32] compared with Europeans, but the analyses were adjusted for these possible differences. There might be ethnic-specific genetic differences in susceptibility for acne, but for now this is not documented in the largest genome-wide association study.[33] However, the sensitivity analyses showed that the additional adjustment for ethnicity did not change the significant effect of the darker skin color on acne severity. Some small studies have looked at ethnic differences of the sebaceous gland, but no differences in either biology or function were found.[34-36] However, Davis et al. and Falder et al. showed that histologically a higher degree of inflammation was visible in biopsies of noninflammatory acne lesions in darker skin,[34,37] hypothesizing this might be the reason for the development of post-inflammatory hyperpigmentation already when having only mild acne. However, all these studies contained few patients and, in the light of our results, will need to be researched more thoroughly. Another possible underlying factor for more severe acne in children with darker skin colors could be the more frequent use of oily skin/hair products causing acne pomade.[34,38]

Lastly, being overweight was associated with more severe acne in boys. Several studies have reported the relation of being overweight with more severe acne before. A pooled OR of 2.36 (95% CI, 1.97-2.83) of overweight/obese BMI in comparison to normal/underweight BMI was calculated by Heng et al.[1] Higher BMI may be associated with higher glycemic loads and higher androgen levels which cause a higher sebum production.[25]

Strengths and limitations

There are several strengths of this study. First of all, it has a large sample size with a multiethnic population which is an accurate representation of the population of Rotterdam.[39] Additionally, to our knowledge, this is the first study to use 2 trained physicians (and a third dermatologist if needed) to score acne in a large multiethnic population for the most accurate prevalence numbers in this age group. Finally, this study analyzed multiple variables that have been associated with acne severity separately in the past, simultaneously to allow for adjusting.

However, a cross-sectional study design limits the exploration of causal relations. We investigated relatively young adolescents and the findings are likely to be striking in higher age groups. Additionally, the sex-specific Tanner stages enabled us to analyze both sexes separately and not look at the population as a whole.

Although we used a validated scale for grading the acne severity, it was validated using photographs of 34 individuals. In our study, a greater heterogeneity in acne was observed. In addition, it was not validated for grading darker skin which could have

led to misclassifications due to a harder differentiation between active and postinflammatory lesions on photographs of adolescents with darker skin. To minimalize this bias, a larger proportion of these photos was discussed with the dermatologist.

Lastly, there was no information on acne treatment exposure during the time the three-dimensional photo was taken. However, the proportion of children who reported to have acne and ever had acne treatment according to their parents was low (14% and 19% for boys and girls respectively, of which <1% used systemic treatment) and therefore has a limited effect.

CONCLUSION

At the age of 13, about half the adolescents suffered from acne. Girls had more severe acne than boys mainly because of an earlier onset of puberty. Additional determinants for the development of more severe acne were having a darker skin color and being overweight. Future studies are needed to better understand the biology between acne in darker compared with lighter skin color.

Conflicts of interest

Author Witkam was financially supported by L'Oréal. Authors Dal Belo, Pourhamidi, Raynaud, Moreau, and Aguilar are employees of L'Oréal and had a role on the analysis and writing of the manuscript. The other authors have no conflicts of interest to declare.

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JAAD Game changer

JAAD Game Changer: Assessment of major comorbidities in adults with atopic dermatitis using the Charlson comorbidity index

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How did this article change the practice of dermatology?

- Although this article focuses on assessing comorbidities, the association between major comorbidities, adults with atopic dermatitis and smoking is very interesting.
- This gives focus to our counseling to adults with atopic dermatitis, with emphasis on modifiable lifestyle changes such as smoking in efforts to treat the whole patient.

Conflicts of interest: None disclosed.

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