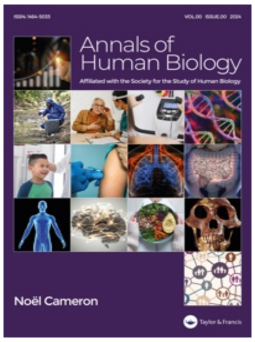

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Dynamics of facial indices from 10 to 20 years of age: a comparison of direct anthropometry and photoanthropometry

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ABSTRACT

Background: Facial indices are used for facial proportions analysis. So far, studies have investigated only a few indices or a narrow age range. Studies comparing direct anthropometry and photoanthropometry for facial analysis are contradictory.
Aim: The aim of this study was to analyse the dynamics of facial indices from 10 to 20 years of age and to determine the indices which were consistent between direct anthropometry and photoanthropometry.
Subjects and methods: Faces of 1376 participants were measured directly and photographed in the frontal plane. Craniofacial landmarks were identified, facial parameters were measured, 34 facial indices were calculated. Their dynamics and sexual differences were analysed.
Results: Interpupillary distance relative to morphological facial height gradually decreased while facial index increased. Zygomandibular index remained stable. Nasal index for boys varied the most. Nasal width relative to facial heights remained stable. Interpupillary distance in relation to morphological facial height and labial fissure width showed the best consistency between the two methods.
Conclusion: Eyes became relatively smaller. Faces grew vertically relatively more than horizontally. The nose became wider at a similar rate as the face grew vertically. Indices containing vertical measurements, eye parameters and labial fissure width coincided the most between the two methods.

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Anthropometry; facial indices; photoanthropometry

Introduction

Adolescence is a period of the most rapid facial growth (Nahhas et al. 2014; Farnell et al. 2021). Facial proportions can change significantly over a few years during puberty (Koudelová et al. 2019). For example, there is substantial evidence indicating that the forehead becomes relatively smaller in comparison with the whole face, or that the nose and the chin undergo structural changes by becoming more protruding (H. Li et al. 2022). The face grows vertically more than horizontally during puberty and the most significant changes occur in midface height and lower facial height in both sexes (Yeo et al. 2022).

Classical anthropometry is considered the golden standard and the most accurate method of facial analysis (Farkas 1994). However, taking measurements on living participants is time-consuming. An alternative method to gain an understanding of facial growth and development is the investigation of 2D images which is low-cost and convenient (Machado et al. 2019; Flores et al. 2019; Ayaz et al. 2020). Facial images are used in aesthetic surgery and orthodontics for treatment planning and evaluation (Balel et al. 2023; Moorefield et al. 2023). Facial photographs are used in biological anthropology for determining the

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differences between sexes, age groups, and populations (Sepehr et al. 2012; Bahşi et al. 2021). Finally, facial photographs aid forensic investigations. A recent study has revealed accuracy of 69.3% in age estimation from photographs of children (Damascena et al. 2024). This indicates that further studies in children and adolescent populations are required.

A convenient method used to investigate facial proportions across age is the calculation of facial indices—the relations between two parameters. However, studies applying this method are scarce. The most thorough facial analysis based on 129 facial indices of North American Caucasians aged 6 to 18 years was conducted by Farkas in 1994. Later Farkas and co-authors published an additional study on facial indices of children aged 1 to 5 (Farkas 1994; Farkas et al. 2003). Studies restricted to one age group (12 years) examined eleven facial indices of 80 Chinese and 80 Caucasian children of both sexes from Hong Kong (Lundström and Cooke 1991) and twenty-two facial indices of children of the Chinese population (Yeung et al. 2015). A few studies researched indices restricted to one facial region, such as the nose (Jahanbin et al. 2012; Likus et al. 2025) or eyes (Ye et al. 2022; Scendoni et al. 2023). The indices of the lips and the chin were investigated in young adults (Anic-Milosevic et al. 2010). The facial and cephalic indices stand out as those more broadly analysed (Grabcika et al. 2024; Jeon et al. 2024; Dabhi et al. 2025; Likus et al. 2025). One of the most recent studies focused on a large number of facial indicators in children within the age range of 3.5–14.5 years, however only 85 participants were included (Ogodescu et al. 2021).

To our knowledge, most studies comparing facial measurements obtained from 2D photographs with those from direct anthropometry have focused on adult populations (Anas et al. 2019; Lim et al. 2022), which suggests that additional research on the faces of children and adolescents is needed. It is known that the craniofacial structure and shape of children differ from adults (Kesterke et al. 2016). What is more, the craniofacial parameters of boys differ from those of girls (Gu et al. 2024). Research shows the differences in the facial shape of males and females present in each age group from 3 to 25 years of age (Kesterke et al. 2016).

Given the lack of studies focussing on a broad spectrum of facial indices, especially during adolescence, such a study would significantly contribute to the literature. Considering the fact that the face does not grow evenly (Kesterke et al. 2016), we aimed to investigate the dynamics of facial proportions. As a rule, studies analyse faces using one method, e.g. photographs or direct anthropometry. Even though some studies compare facial investigation methods, they tend to include only adult populations (Lim et al. 2022; Cascos et al. 2023; Choudhary et al. 2024). Therefore, more detailed studies are needed to analyse facial proportions in adolescence. As for the use of different investigation methods, there could be a difference between the accuracy of the 2D method compared to a classical method among different age groups.

The aim of this study was to investigate the dynamics of facial indices from 10 to 20 years of age using direct anthropometry and photoanthropometry methods. In addition, we aimed to determine the indices which did not differ between the two methods. The objective was to investigate the proportions of the same facial regions (e.g. nose, eyes) and the relationship of the parameters of different facial regions (e.g. eye parameters in relation to vertical parameters). Therefore, the indices were attributed to different groups: 1) indices containing eye parameters; 2) nasal width and height; 3) labial fissure width; 4) main transverse parameters.

Material and methods

Study design

This study analysed facial indices obtained from direct facial anthropometry measurements during adolescence. In addition, we calculated and compared facial indices obtained not only from direct anthropometry but also from professionally taken photographs. Participants aged 10 to 20 years without facial surgeries, cosmetic procedures, craniofacial anomalies or facial traumas were included in the study. Faces of participants were measured by a classical anthropometric method and, additionally, were professionally photographed in the Frankfort Horizontal plane. All the participants older than 16 years, or parents of participating children younger than 16 years of age, signed an informed consent form. Data were coded and a code was attributed to each participant of the study. This study was conducted as part of the EC project ISEC (JLS/2007/ISEC/451) and EC project AGIS (JLS/2005/AGIS/054). The Lithuanian Bioethics Committee approved the study (Approval No. 6B-09-264).

Direct anthropometry measurements

A total of 689 boys and 687 girls aged 10 to 20 years old were included. Faces were measured using anthropometric tools according to the standard methodology of direct facial anthropometry as described by Farkas (Farkas 1994). Martin-type anthropometric instruments (GPM—*Siber Hegner*, Zurich) were used, including a sliding calliper, a small spreading calliper and an anthropometer. The heads of all participants were positioned in the Frankfort Horizontal plane. All participants were seated. The measuring technique was standardised among three investigators. To avoid inter- and intra-observer errors, the measurements were compared. The errors for the measurements including landmarks related to skeletal structures, for example, *gnathion* or *subnasale,* varied by ±1mm. Some landmarks were difficult to palpate, such as *gnathion*—the measurement errors for those landmarks varied by approximately ±3mm.

In total, eighteen craniofacial landmarks were identified (Figure 1). Ten facial measurements were acquired (Table 1). The *sellion* landmark (the deepest point in the midline of the frontonasal contour at the nasal root (Katina et al. 2016)) can be more accurately determined than the *nasion*, therefore, it was chosen instead of the *nasion*.

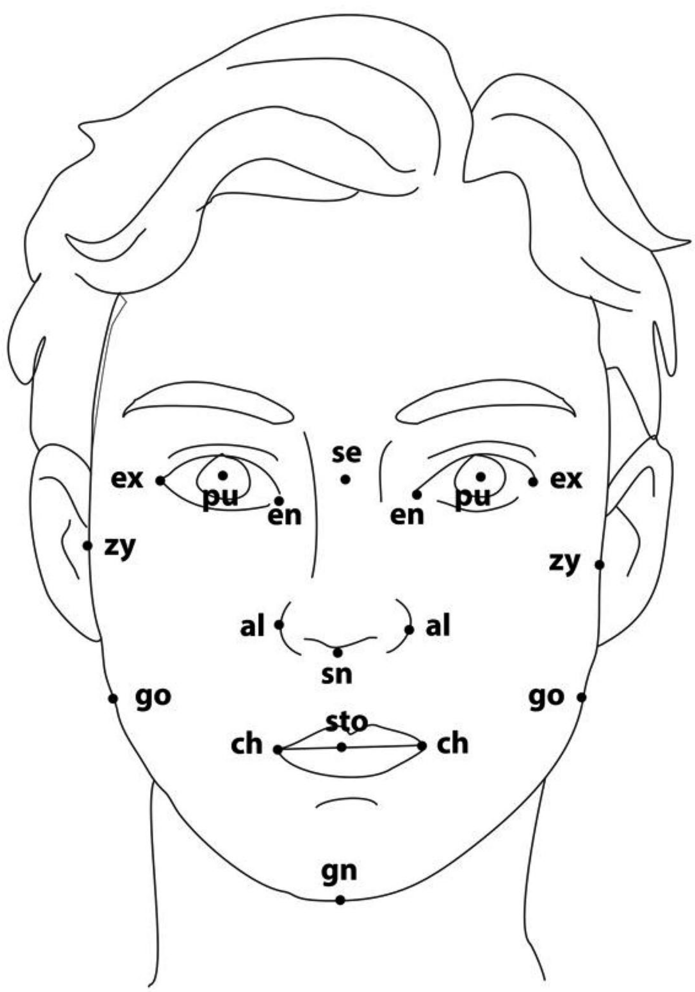

Figure 1. Localisation of anthropometric landmarks on front-face picture (zy: zygion; go: gonion; se: sellion; gn: gnathion; pu: pupillare; en: endocanthion; ex: exocanthion; al: alare; ch: cheilion; sto: stomion; sn: subnasale).

Table 1. Description of craniofacial measurements.

Measurement (landmark abbreviations)	Measurement description
1. Morphological facial height (se-gn)	Distance between *sellion*—the deepest point in the midline of the frontonasal soft tissue contour at the nasal root and the mid-point of the chin the most anteriorly-inferiorly
2. Physiognomic upper facial height (se-sto)	Distance between *sellion*—the deepest point in the midline of the frontonasal soft tissue contour at the nasal root and *stomion*—the midpoint of the horizontal labial fissure (mouth closed)
3. Bizygomatic width (face width) (zy-zy)	Maximal distance between *zygion* landmarks (the right and left most lateral points of zygomatic arch)
4. Bigonial width (mandible width) (go-go)	Distance between *gonions* (the most lateral points of the mandibular angles)
5. Intercanthal width (en-en)	Distance between *endocanthion* landmarks—right and left most inner angles of palpebral fissures
6. Biocular width (ex-ex)	Distance between *exocanthion* landmarks—right and left most lateral angles of palpebral fissures
7. Interpupillary distance (pu-pu)	Distance between *pupillare* landmarks - centres of the right and left pupils (eyes focused straightforward)
8. Nasal height (se-sn)	Distance between *sellion*—the deepest point in the midline of the frontonasal soft tissue contour at the nasal root and the point at the midline of the nasal base where the tissue between nostrils and the skin of the upper lip meet
9. Nasal width (al-al)	Distance between *alare* landmarks—right and left the most lateral points of the nose wings
10. Labial fissure width (mouth width) (ch-ch)	Distance between *cheilion* landmarks—the right and left labial corners (mouth closed)

Zy: zygion; go: gonion; se: sellion; gn: gnathion; pu: pupillare; en: endocanthion; ex: exocanthion; al: alare; ch: cheilion; sto: stomion; sn: subnasale.

Taking photographs

After measuring, the faces of the same participants were photographed using a digital camera. The heads of the participants were positioned in the Frankfort Horizontal plane (Santos et al. 2017). All participants were seated and a homogeneous light background was applied. The facial expression had to be neutral with eyes open, participants were not allowed to wear eyeglasses. Faces and ears had to be unobstructed by hair, including a beard or a moustache.

The focus point was chosen as the *sellion* landmark. It was used instead of the *nasion* as the *nasion* could have been difficult to identify in the indirect craniofacial methodology (Bahşi et al. 2021). The *trichion* point (a landmark at the midline of hair growth line anteriorly) is problematic to determine from front-face photographs and even in 3D facial scans it appeared to be poorly reproducible (Z. Li et al. 2022), therefore, it was not used in our study. The *frontotemporale* landmark cannot be accurately identified in 2D images (Cummaudo et al. 2013; Machado et al. 2019). Therefore, it was not investigated in this study. The digital camera was placed at a distance of 1.5 metres from the *sellion* point.

Placing anthropometric landmarks and measuring facial parameters in photographs

Using *ImageJ* software, eighteen facial landmarks were manually placed on all photographs (Figure 1). The distance between the two landmarks was measured in pixels. In total, ten facial measurements were acquired (Table 1). Before measuring all photographs, a pilot study was performed to check for reliability. The main investigator measured ten photographs three times during 24-hour intervals. Using the intraclass correlation coefficient, the intra-observer agreement was determined and was excellent – 0.999. Two other investigators then measured the same photographs. The inter-observer agreement was also excellent – 0.994. After this exercise, the main investigator measured ten facial parameters in 1376 front-face photographs of participants.

Calculation of facial indices

Facial indices were calculated to compare the measurements taken by direct anthropometry and by measuring photographs. We used facial indices according to Farkas (Farkas 1994; Farkas et al. 2003) and additionally calculated more indices according to our previous study (Stukaite-Ruibiene et al. 2024). The choice was made to include indices which contained the *gonion* landmark as well.

The parameters measured by direct anthropometry were taken in millimetres while the parameters obtained from photographs were measured in pixels. Therefore, facial indices were used to enable the

Table 2. List of facial indices calculated.

Indices containing eye parameters	Indices containing nasal width and height	Indices containing labial fissure width	Indices containing main transverse parameters—bizygomatic and bigonial widths
en-en/pu-pu	en-en/al-al	en-en/ch-ch	se-gn/zy-zy (facial index)
en-en/ex-ex	en-en/se-sn	ch-ch/pu-pu	en-en/zy-zy
en-en/se-sto	al-al/pu-pu	ch-ch/ex-ex	en-en/go-go
en-en/se-gn	al-al/ex-ex	ch-ch/go-go	pu-pu/zy-zy
pu-pu/ex-ex	al-al/ch-ch	ch-ch/se-gn	pu-pu/go-go
pu-pu/se-gn	al-al/go-go	ch-ch/se-sto	ex-ex/go-go
pu-pu/se-sto	se-sn/go-go		go-go/zy-zy
se-sto/ex-ex	al-al/se-sn (nasal index)		se-sto/zy-zy
	al-al/se-sto		se-sto/go-go
	al-al/se-gn		go-go/se-gn

Zy: zygion; go: gonion; se: sellion; gn: gnathion; pu: pupillare; en: endocanthion; ex: exocanthion; al: alare; ch: cheilion; sto: stomion; sn: subnasale.

comparison between the two methods. As these indices are ratios of linear measurements, they are dimensionless and independent of scale. Any slight variations in pixel resolution did not affect the results, as ratios were calculated. The indices were obtained by dividing one parameter (usually horizontal or the smaller one) by another (usually vertical or the larger one) and multiplying by 100. In total, 34 facial indices were calculated (Table 2).

The indices were distributed into four groups: 1) indices containing eye parameters; 2) indices containing nasal width and height; 3) indices containing labial fissure width; 4) indices containing main transverse parameters—bizygomatic and bigonial widths. The indices containing the main facial heights were distributed across four groups according to another facial parameter in the index. The indices attributed to the group containing eye parameters included the indices containing eye parameters only or the eye parameter and the vertical measurement.

All the indices containing nasal parameters were attributed to one group, as well as nasal width in relation to labial fissure width (al-al/ch-ch), nasal width in relation to bigonial width (al-al/go-go) and nasal height in relation to bigonial width (se-sn/go-go)—it was done according to the parameter in the numerator.

All the indices containing labial fissure width were attributed to a separate group except the above-mentioned nasal width in relation to labial fissure width (al-al/ch-ch). Labial fissure width in relation to bigonial width (ch-ch/go-go) was also attributed to labial fissure width group according to the numerator. All the remaining indices containing the main transverse parameters were attributed to one group.

Statistical analysis

Data distribution was checked using the Shapiro-Wilk test of normality. As the data were normally distributed, the Student's t-test was applied. All tests were performed using SPSS® 28.0 software (IBM®, New York, USA). The level of significance was set at 5% ($p < 0.05$). Facial indices showed statistically significant differences between data calculated from direct anthropometry and from photographs if $p < 0.05$, no statistically significant differences were observed if $p \geq 0.05$. If indices between the two methods did not show statistically significant differences it was considered that the indices calculated from direct anthropometry and from photographs agreed and could be used interchangeably. Sexual dimorphism was evaluated using Student's t-test—if $p < 0.05$, facial indices significantly differed between the sexes. Linear regression was used to determine whether the indices gradually changed with age from 10 to 20 years.

Results

Dynamics of facial indices containing eye parameters calculated using direct anthropometry measurements

The growth of the eye region was quite even in girls—intercanthal width in relation to biocular width (en-en/ex-ex) did not differ between the subjects of 10 and 20 years of age ($p < 0.05$) (Table 3). This index

Table 3. Means and standard deviations of indices containing eye parameters from 10 to 20 years of age (*p*-value in the last column shows the comparison of the means of anthropometrically determined indices between the 10- and 20-year-old age groups for boys and girls separately).

Index	Age		10	11	12	13	14	15	16	17	18	19	20	*p*-value
en-en/pu-pu (intercanthal width in relation to interpupillary distance)	Boys	AnthrInd	**53.42 ± 2.95**	54.89 ± 3.90	53.64 ± 3.71	52.55 ± 4.00	**52.06 ± 3.34**	**52.66 ± 4.22**	51.80 ± 3.06	**51.04 ± 3.53**	50.94 ± 3.59	**50.01 ± 3.91**	**50.43 ± 3.72**	<0.001
		PhotoInd	**52.81 ± 2.73**	52.23 ± 3.48	52.02 ± 3.17	50.79 ± 2.85	**51.23 ± 2.90**	**50.95 ± 3.71**	50.04 ± 2.60	**49.98 ± 2.88**	49.39 ± 3.22	**49.44 ± 2.89**	**49.36 ± 3.60**	
	Girls	AnthrInd	**52.97 ± 3.36**	53.39 ± 3.88	53.16 ± 3.65	**52.45 ± 3.42**	**52.75 ± 2.71**	**52.18 ± 3.67**	**51.75 ± 3.54**	**52.42 ± 3.52**	52.25 ± 340	**51.45 ± 3.81**	51.28 ± 3.48	<0.01
		PhotoInd	**52.66 ± 3.18**	52.30 ± 3.28	51.75 ± 3.28	**51.54 ± 2.84**	**51.41 ± 2.48**	**51.02 ± 2.80**	**51.12 ± 2.90**	**51.39 ± 2.68**	50.64 ± 3.15	**50.60 ± 3.19**	50.06 ± 2.98	
en-en/ex-ex (intercanthal width in relation to biocular width)	Boys	AnthrInd	**36.16 ± 2.16**	37.18 ± 2.21	**36.30 ± 2.48**	**35.28 ± 3.38**	**34.76 ± 2.90**	**35.90 ± 3.02**	35.69 ± 2.01	**35.06 ± 2.45**	35.20 ± 2.35	**34.44 ± 2.56**	35.13 ± 2.69	<0.05
		PhotoInd	**35.99 ± 1.95**	35.51 ± 2.47	**35.50 ± 2.12**	**34.59 ± 2.13**	**35.42 ± 2.03**	**34.83 ± 2.58**	34.46 ± 1.96	**34.49 ± 2.23**	33.71 ± 2.51	**33.85 ± 2.24**	34.06 ± 2.62	
	Girls	AnthrInd	35.18 ± 2.50	**35.91 ± 2.65**	**35.78 ± 2.44**	**35.32 ± 2.51**	**35.08 ± 2.32**	**34.85 ± 2.72**	**34.41 ± 2.58**	**34.70 ± 2.41**	**34.77 ± 2.23**	**35.54 ± 2.73**	35.06 ± 2.35	>0.05
		PhotoInd	36.45 ± 2.20	**36.14 ± 2.21**	**35.71 ± 2.36**	**35.44 ± 2.11**	**35.53 ± 1.84**	**35.07 ± 2.27**	**34.91 ± 2.28**	**35.06 ± 2.05**	**34.31 ± 2.24**	**34.63 ± 2.09**	34.30 ± 2.14	
en-en/se-sto (intercanthal width in relation to physiognomic upper facial height)	Boys	AnthrInd	**47.31 ± 4.72**	49.05 ± 5.78	**46.64 ± 4.30**	45.17 ± 4.65	**44.34 ± 3.38**	44.71 ± 7.53	**43.36 ± 3.19**	**43.08 ± 5.32**	42.58 ± 4.18	**42.25 ± 4.79**	**42.73 ± 4.63**	<0.001
		PhotoInd	**46.80 ± 3.36**	45.43 ± 4.53	**45.75 ± 3.93**	43.22 ± 3.67	**44.03 ± 3.88**	42.18 ± 4.34	**42.35 ± 3.27**	**42.22 ± 3.77**	41.05 ± 4.01	**41.47 ± 3.86**	**41.44 ± 4.39**	
	Girls	AnthrInd	**46.79 ± 4.83**	**47.67 ± 4.84**	**46.97 ± 4.34**	**45.78 ± 4.95**	**45.48 ± 3.27**	**45.88 ± 4.24**	**44.85 ± 4.33**	**45.62 ± 4.92**	45.91 ± 4.64	**45.81 ± 5.23**	45.59 ± 3.80	<0.01
		PhotoInd	**46.96 ± 4.20**	**47.46 ± 4.32**	**46.13 ± 4.25**	**45.10 ± 3.92**	**45.36 ± 3.17**	**45.43 ± 3.72**	**45.39 ± 4.12**	**45.63 ± 4.15**	43.70 ± 3.78	**44.53 ± 4.58**	43.19 ± 3.45	
en-en/se-gn (intercanthal width in relation to morphological facial height)	Boys	AnthrInd	**29.55 ± 2.37**	**29.85 ± 2.39**	**29.22 ± 2.57**	28.46 ± 2.88	**27.46 ± 2.04**	**27.62 ± 3.06**	27.62 ± 2.11	**26.76 ± 2.69**	26.85 ± 2.55	**26.38 ± 2.81**	**26.73 ± 2.97**	<0.001
		PhotoInd	**29.57 ± 2.26**	**28.87 ± 2.77**	**28.91 ± 2.45**	27.05 ± 2.36	**27.58 ± 2.25**	**26.83 ± 2.74**	26.64 ± 1.93	**26.56 ± 2.47**	25.84 ± 2.44	**25.94 ± 2.28**	**26.10 ± 3.66**	
	Girls	AnthrInd	**30.31 ± 3.16**	**30.94 ± 2.96**	30.45 ± 2.87	**29.86 ± 2.83**	**29.82 ± 2.21**	29.91 ± 2.96	**29.28 ± 2.70**	**29.69 ± 2.95**	29.65 ± 2.63	**28.98 ± 2.91**	**27.95 ± 2.48**	<0.001
		PhotoInd	**29.73 ± 2.77**	**30.15 ± 2.72**	29.29 ± 2.69	**28.86 ± 2.34**	**28.92 ± 2.09**	28.67 ± 2.37	**28.42 ± 2.44**	**28.88 ± 2.46**	28.40 ± 3.24	**28.19 ± 2.66**	**27.37 ± 2.17**	
pu-pu/ex-ex (interpupillary distance in relation to biocular width)	Boys	AnthrInd	**67.59 ± 1.97**	**67.84 ± 2.74**	**67.76 ± 3.05**	**67.17 ± 4.57**	66.89 ± 5.34	**68.27 ± 3.85**	**68.93 ± 1.59**	**68.71 ± 2.48**	69.17 ± 2.31	**68.93 ± 2.20**	**69.73 ± 3.42**	<0.001
		PhotoInd	**68.16 ± 1.32**	**67.98 ± 1.51**	**68.26 ± 1.47**	**68.08 ± 1.22**	69.14 ± 1.50	**68.37 ± 1.46**	**68.66 ± 1.42**	**69.00 ± 1.60**	68.24 ± 2.15	**68.46 ± 1.43**	**68.99 ± 1.55**	
	Girls	AnthrInd	66.43 ± 2.77	67.30 ± 2.27	67.36 ± 2.76	67.33 ± 1.92	66.49 ± 2.59	66.81 ± 2.65	66.49 ± 2.07	66.22 ± 2.45	66.60 ± 2.70	**69.09 ± 2.16**	**68.43 ± 2.70**	<0.001
		PhotoInd	69.23 ± 1.55	69.12 ± 1.33	69.01 ± 1.59	68.76 ± 1.30	69.11 ± 1.07	68.72 ± 1.49	68.26 ± 1.34	68.21 ± 1.43	67.76 ± 1.95	**68.47 ± 1.51**	**68.52 ± 1.57**	
pu-pu/se-gn (interpupillary distance in relation to morphological facial height)	Boys	AnthrInd	**55.31 ± 3.24**	**54.44 ± 3.23**	**54.47 ± 2.86**	**54.17 ± 3.93**	**52.79 ± 2.78**	**52.44 ± 3.76**	**53.33 ± 2.68**	**52.43 ± 3.73**	**52.70 ± 3.07**	**52.71 ± 3.29**	**52.95 ± 52.78**	<0.001
		PhotoInd	**55.98 ± 2.79**	**55.22 ± 3.03**	**55.56 ± 2.86**	**53.23 ± 2.98**	**53.82 ± 2.94**	**52.62 ± 3.13**	**53.18 ± 2.54**	**53.10 ± 3.29**	**52.27 ± 2.99**	**52.42 ± 2.48**	**52.78 ± 5.21**	
	Girls	AnthrInd	**57.15 ± 3.92**	**57.94 ± 3.49**	**57.28 ± 3.65**	**56.90 ± 3.47**	**56.54 ± 3.00**	**57.30 ± 3.71**	**56.54 ± 2.72**	**56.57 ± 3.41**	**56.74 ± 3.43**	**56.28 ± 3.38**	**54.52 ± 3.46**	<0.001
		PhotoInd	**56.42 ± 3.30**	**57.63 ± 3.51**	**56.57 ± 3.38**	**56.00 ± 3.22**	**56.23 ± 2.80**	**56.16 ± 2.71**	**55.54 ± 2.68**	**56.15 ± 2.82**	**56.02 ± 4.67**	**55.67 ± 3.27**	**54.65 ± 2.52**	
pu-pu/se-sto (interpupillary distance in relation to physiognomic upper facial height)	Boys	AnthrInd	**88.59 ± 8.05**	**89.46 ± 10.05**	**86.94 ± 4.89**	**85.98 ± 6.40**	**85.25 ± 4.98**	**84.84 ± 12.17**	**83.74 ± 4.37**	**84.38 ± 8.33**	**83.55 ± 5.17**	**84.37 ± 4.95**	**84.65 ± 5.33**	<0.001
		PhotoInd	**88.61 ± 4.03**	**86.89 ± 5.25**	**87.96 ± 5.11**	**85.06 ± 4.80**	**85.90 ± 5.29**	**82.70 ± 4.38**	**84.58 ± 5.04**	**84.43 ± 4.97**	**83.04 ± 4.96**	**83.81 ± 4.90**	**83.85 ± 4.78**	
	Girls	AnthrInd	**88.30 ± 6.86**	**89.26 ± 5.80**	88.36 ± 5.76	**87.17 ± 6.15**	**86.25 ± 4.93**	87.94 ± 5.22	86.59 ± 4.55	86.90 ± 5.97	**87.84 ± 6.52**	**88.92 ± 6.39**	**86.99 ± 5.31**	>0.05
		PhotoInd	**89.12 ± 4.75**	**90.72 ± 5.46**	89.10 ± 5.25	**87.48 ± 5.44**	**88.24 ± 4.70**	89.00 ± 4.52	88.69 ± 4.66	88.68 ± 5.00	**86.29 ± 5.20**	**87.89 ± 5.53**	**86.26 ± 4.44**	

(*Continued*)

Table 3. Continued.

Age / Index			10	11	12	13	14	15	16	17	18	19	20	*p*-value
se-sto/ex-ex (physiognomic upper facial height in relation to biocular width	Boys	AnthrInd	**77.20 ± 4.84**	**76.48 ± 6.60**	**78.17 ± 5.46**	**78.45 ± 6.99**	**78.65 ± 6.99**	**81.43 ± 8.32**	**82.51 ± 4.26**	**81.99 ± 6.50**	**83.05 ± 5.25**	**81.98 ± 5.49**	**82.68 ± 6.33**	<0.001
		PhotoInd	**77.04 ± 3.08**	**78.47 ± 4.11**	**77.84 ± 3.83**	**80.25 ± 4.01**	**80.73 ± 4.31**	**82.86 ± 4.06**	**81.35 ± 4.57**	**81.96 ± 4.34**	**82.41 ± 4.65**	**81.91 ± 4.44**	**82.51 ± 4.47**	
	Girls	AnthrInd	75.57 ± 5.19	**75.67 ± 4.97**	**76.48 ± 4.85**	**77.59 ± 5.45**	**77.29 ± 4.76**	**76.16 ± 4.16**	**76.95 ± 4.01**	**76.48 ± 4.74**	76.12 ± 5.05	**78.05 ± 5.49**	**78.88 ± 4.65**	<0.001
		PhotoInd	77.88 ± 4.01	**76.43 ± 4.28**	**77.67 ± 4.26**	**78.85 ± 4.17**	**78.52 ± 4.08**	**77.37 ± 3.41**	**77.14 ± 3.65**	**77.12 ± 3.96**	78.75 ± 4.36	**78.17 ± 4.71**	**79.61 ± 3.97**	

In bold—no statistically significant difference between indices calculated from direct anthropometry and from photographs ($p \geq 0.05$), therefore, these methods could be used interchangeably.
AnthrInd—antropometrically determined indices.
PhotoInd—indices determined from photographs.
statistically significant difference between boys and girls' indices calculated from direct anthropometry measurements ($p < 0.05$).

in boys gradually decreased and at 20 years of age was smaller than at 10 years ($p < 0.05$), meaning the distance between the outer corners of the palpebral fissure grew faster than the distance between the inner corners of the palpebral fissure. Intercanthal width in relation to interpupillary distance (en-en/pu-pu) was smaller at 20 years of age than at 10 years in both boys ($p < 0.001$) and girls ($p < 0.01$).

Most indices containing eye parameters and vertical measurements differed between 10 and 20 years of age and had clear dynamics tendencies except for interpupillary distance in relation to the physiognomic upper facial height (pu-pu/se-sto) in girls ($p > 0.05$) (Table 3). The linear regression analysis also did not show an association with age. Interpupillary distance in relation to morphological facial height (pu-pu/se-gn) and intercanthal width in relation to morphological facial height (en-en/se-gn) were indices which showed a significant sexual dimorphism throughout the entire time period. They were significantly larger in girls ($p < 0.05$) which means that the faces of boys were relatively longer and the horizontal distances between landmarks of the eyes were relatively smaller in boys. These indices significantly decreased in both sexes from 10 to 20 years of age ($p < 0.001$)—the faces grew faster vertically than the eyes horizontally, while the eyes decreased in size relative to the entire face.

Interpupillary distance relative to physiognomic upper facial height (pu-pu/se-sto) and intercanthal width relative to physiognomic upper facial height (en-en/se-sto) showed similar values between the sexes at the start of adolescence but later the girls' indices became much larger than those of the boys ($p < 0.05$) showing a more evident growth spurt of the vertical upper facial part in boys. As for the physiognomic upper facial height in relation to biocular width (se-sto/ex-ex), the values in boys and girls were similar between 10 and 14 years of age, however, from 15 to 20 years, the boys' index showed a more evident increase ($p < 0.05$). This reflects that the faces of the boys grew vertically more and remained relatively longer (compared to biocular width) than those of the girls.

Dynamics of facial indices containing nasal parameters calculated using direct anthropometry measurements

Among the indices containing nasal parameters, intercanthal width in relation to nasal width (en-en/al-al) showed the greatest change among all 34 calculated indices (Table 4). Linear regression showed a strong tendency of a gradual decrease ($p < 0.001$). From the age of 11, this index in boys began to decrease rapidly and from the age of 14 it became significantly smaller than that of girls ($p < 0.05$) showing a more noticeable widening of the nose in boys compared to girls. Intercanthal width in relation to nasal height (en-en/se-sn) decreased rapidly in both sexes as well, meaning the nose became relatively wider and longer, and the eye area became relatively smaller. From the age of 17, the index between intercanthal width and nasal height (en-en/se-sn) in girls became significantly larger ($p < 0.05$) reflecting relatively longer noses in boys.

Nasal parameters in girls grew relatively more evenly than in boys. The most age-stable indices containing nasal parameters in both boys and girls were nasal width in relation to morphological facial height (al-al/se-gn) and nasal width in relation to physiognomic upper facial height (al-al/se-sto). What is more, the linear regression analysis did not show any tendency of a gradual increase or decrease in nasal width in relation to the physiognomic upper facial height (al-al/se-sto) for either of the sexes during the entire time period. In general, the nose became wider in parallel with the vertical facial growth in both sexes while the proportions of nasal width relative to vertical facial parameters remained largely stable.

In girls aged between 10 and 20 years, there were no significant differences observed in nasal height in relation to bigonial width (se-sn/go-go) ($p > 0.05$), nasal width in relation to bigonial width (al-al/go-go) ($p > 0.05$), and nasal width in relation to labial fissure width (al-al/ch-ch) ($p > 0.05$). However, the linear regression analysis showed that only nasal width in relation to bigonial width (al-al/go-go) remained relatively stable and did not reveal any gradual tendency of changes related with the age in girls. This could indicate the proportional widening of the nose and the jaw in girls.

In contrast to a barely noticeable increase in girls, the nasal height in relation to bigonial width index (se-sn/go-go) increased significantly in boys aged 11–14 (reflecting a growth spurt in boys' nasal height relative to jaw width). In boys, the index was significantly larger at 20 years of age than at 10 years of age ($p < 0.001$). As for more sexual differences, the ratio of nasal width to labial fissure width (al-al/ch-ch)

Table 4. Means and standard deviations of indices containing nasal width and height from 10 to 20 years of age (*p*-value in the last column shows the comparison of the means of anthropometrically determined indices between the 10- and 20-year-old age groups for boys and girls separately).

Index	Age		10	11	12	13	14	15	16	17	18	19	20	*p*-value
en-en/al-al (intercanthal width in relation to nasal width)	Boys	AnthrInd	103.06 ± 10.19	103.85 ± 8.72	99.44 ± 8.83	96.18 ± 10.83	92.12 ± 7.50	93.50 ± 10.19	92.75 ± 8.00	89.53 ± 8.63	90.27 ± 9.08	87.97 ± 9.26	89.89 ± 7.58	<0.001
		PhotoInd	90.75 ± 6.49	90.85 ± 8.96	90.88 ± 7.95	86.1 ± 8.32	85.14 ± 7.63	85.16 ± 7.66	83.63 ± 7.01	82.37 ± 7.46	81.97 ± 7.55	82.06 ± 7.66	82.40 ± 7.10	
	Girls	AnthrInd	103.45 ± 10.47	103.64 ± 10.37	101.83 ± 10.53	98.61 ± 7.95	98.69 ± 10.81	98.68 ± 9.57	99.40 ± 10.28	102.07 ± 9.36	100.64 ± 9.38	95.62 ± 11.26	96.50 ± 9.12	<0.001
		PhotoInd	91.00 ± 7.97	90.14 ± 8.06	88.00 ± 8.05	86.53 ± 7.07	85.42 ± 8.12	86.59 ± 7.02	86.91 ± 7.57	88.87 ± 7.15	88.26 ± 8.52	87.97 ± 7.95	88.59 ± 7.90	
en-en/se-sn (intercanthal width in relation to nasal height)	Boys	AnthrInd	70.87 ± 7.79	74.45 ± 9.01	69.09 ± 6.59	67.37 ± 8.17	64.69 ± 6.92	64.44 ± 8.20	63.56 ± 5.53	62.66 ± 7.31	62.78 ± 6.78	61.29 ± 7.86	61.74 ± 7.82	<0.001
		PhotoInd	67.42 ± 5.28	64.81 ± 6.64	65.13 ± 6.17	59.94 ± 5.7	61.79 ± 6.11	58.54 ± 6.78	58.66 ± 5.05	59.1 ± 5.69	58.07 ± 6.35	58.24 ± 5.88	57.95 ± 6.91	
	Girls	AnthrInd	**69.36 ± 7.72**	71.25 ± 8.2	70.26 ± 7.42	66.89 ± 7.86	**65.56 ± 4.80**	66.11 ± 7.37	**64.65 ± 6.72**	**65.53 ± 7.64**	65.91 ± 7.31	66.14 ± 8.60	64.23 ± 6.76	<0.001
		PhotoInd	**67.41 ± 6.69**	67.47 ± 6.83	64.83 ± 6.54	62.54 ± 6.03	**64.17 ± 5.16**	63.14 ± 5.58	**63.25 ± 6.46**	**63.63 ± 5.98**	60.22 ± 5.57	61.42 ± 6.90	59.96 ± 5.58	
al-al/pu-pu (nasal width in relation to interpupillary distance)	Boys	AnthrInd	52.22 ± 4.76	53.03 ± 3.50	54.13 ± 3.45	55.01 ± 4.54	56.77 ± 4.85	56.62 ± 4.13	56.10 ± 4.17	57.29 ± 4.21	56.72 ± 4.17	57.14 ± 4.33	56.29 ± 4.03	<0.001
		PhotoInd	58.34 ± 2.99	57.76 ± 3.72	57.49 ± 4.01	59.30 ± 3.99	60.44 ± 3.99	60.02 ± 3.62	60.18 ± 4.55	60.99 ± 4.52	60.51 ± 3.90	60.56 ± 4.34	60.10 ± 3.93	
	Girls	AnthrInd	51.54 ± 4.41	51.76 ± 3.75	52.54 ± 4.43	53.36 ± 3.47	53.85 ± 4.41	53.12 ± 3.81	52.34 ± 3.60	51.62 ± 4.10	52.17 ± 3.81	54.21 ± 4.64	53.42 ± 4.12	<0.01
		PhotoInd	58.09 ± 3.59	58.23 ± 3.34	59.04 ± 3.64	59.74 ± 2.92	60.51 ± 4.08	59.13 ± 3.55	59.03 ± 3.20	58.06 ± 3.94	57.66 ± 3.97	57.76 ± 3.85	56.76 ± 3.87	
al-al/ex-ex (nasal width in relation to biocular width)	Boys	AnthrInd	35.02 ± 2.34	35.93 ± 2.22	36.67 ± 2.87	36.87 ± 3.21	37.87 ± 3.32	38.61 ± 2.97	38.66 ± 2.90	39.34 ± 2.84	39.21 ± 2.85	39.38 ± 3.23	39.22 ± 3.03	<0.001
		PhotoInd	39.75 ± 1.96	39.25 ± 2.32	39.22 ± 2.52	40.35 ± 2.48	41.77 ± 2.59	41.02 ± 2.38	41.25 ± 2.79	42.05 ± 2.79	41.28 ± 2.80	41.44 ± 2.89	41.45 ± 2.70	
	Girls	AnthrInd	34.18 ± 2.52	34.81 ± 2.41	35.33 ± 2.56	35.92 ± 2.34	35.78 ± 2.97	35.49 ± 2.85	34.77 ± 2.25	34.15 ± 2.48	34.71 ± 2.36	37.43 ± 3.08	36.53 ± 2.89	<0.001
		PhotoInd	40.19 ± 2.23	40.23 ± 2.14	40.72 ± 2.35	41.07 ± 1.91	41.81 ± 2.83	40.61 ± 2.33	40.28 ± 1.94	39.58 ± 2.49	39.05 ± 2.54	39.55 ± 2.74	38.87 ± 2.53	
al-al/ch-ch (nasal width in relation to labial fissure width)	Boys	AnthrInd	67.76 ± 5.14	70.62 ± 5.46	73.15 ± 5.22	72.60 ± 7.14	73.50 ± 6.14	72.1 ± 5.01	72.22 ± 5.92	71.81 ± 5.29	71.62 ± 5.60	71.24 ± 5.65	70.77 ± 5.18	<0.001
		PhotoInd	76.07 ± 4.75	75.45 ± 5.50	76.94 ± 6.47	76.62 ± 5.31	76.69 ± 4.98	75.67 ± 4.48	76.40 ± 5.84	75.7 ± 4.9	75.81 ± 5.03	74.53 ± 5.98	74.38 ± 5.57	
	Girls	AnthrInd	67.59 ± 6.11	67.92 ± 6.12	68.64 ± 5.15	68.25 ± 4.93	67.73 ± 6.89	67.63 ± 6.17	64.64 ± 5.61	63.56 ± 5.83	64.88 ± 4.83	68.13 ± 5.88	67.49 ± 5.36	>0.05
		PhotoInd	75.97 ± 6.18	75.13 ± 5.69	75.59 ± 4.85	74.88 ± 4.16	74.07 ± 6.11	74.00 ± 5.40	72.03 ± 4.78	71.58 ± 5.68	72.48 ± 5.60	72.06 ± 5.93	71.90 ± 4.29	
al-al/go-go (nasal width in relation to bigonial width)	Boys	AnthrInd	30.15 ± 2.68	30.52 ± 2.28	32.81 ± 2.33	31.83 ± 3.03	**33.52 ± 4.09**	**32.61 ± 3.27**	32.26 ± 2.79	32.54 ± 2.36	32.60 ± 2.72	32.81 ± 2.93	31.27 ± 2.36	<0.001
		PhotoInd	32.62 ± 1.92	32.65 ± 2.46	31.65 ± 2.34	33.16 ± 2.21	**34.26 ± 2.61**	**33.30 ± 2.45**	33.42 ± 2.46	34.2 ± 2.39	33.21 ± 2.50	32.82 ± 2.47	32.24 ± 2.27	
	Girls	AnthrInd	31.34 ± 2.72	31.15 ± 2.35	31.48 ± 2.51	32.20 ± 2.68	32.30 ± 2.83	32.26 ± 2.53	31.98 ± 2.28	31.13 ± 2.24	**31.53 ± 2.01**	**31.71 ± 2.66**	**31.27 ± 2.36**	>0.05
		PhotoInd	32.77 ± 1.99	33.11 ± 2.49	33.72 ± 2.02	34.25 ± 2.15	34.12 ± 2.65	33.2 ± 2.42	33.18 ± 2.0	32.71 ± 1.9	**30.95 ± 2.12**	**31.02 ± 2.48**	**30.79 ± 1.88**	
se-sn/go-go (nasal height in relation to bigonial width)	Boys	AnthrInd	**43.86 ± 3.49**	42.79 ± 3.92	**45.58 ± 3.48**	45.49 ± 4.23	**47.87 ± 6.00**	**47.33 ± 3.91**	**47.01 ± 3.14**	**46.59 ± 3.51**	46.88 ± 3.66	47.19 ± 4.10	**47.24 ± 4.04**	<0.001
		PhotoInd	**43.96 ± 3.23**	45.82 ± 3.78	**45.82 ± 3.27**	47.64 ± 3.49	**47.26 ± 3.64**	**48.54 ± 3.32**	**47.66 ± 3.71**	**47.68 ± 3.29**	46.95 ± 3.41	46.30 ± 3.72	**46.09 ± 4.39**	
	Girls	AnthrInd	46.76 ± 3.46	45.44 ± 4.06	45.62 ± 3.47	47.64 ± 4.08	48.49 ± 4.19	48.23 ± 3.96	49.14 ± 3.32	48.63 ± 3.90	48.24 ± 3.36	45.95 ± 4.40	47.06 ± 4.06	>0.05
		PhotoInd	44.34 ± 3.42	44.33 ± 3.96	45.89 ± 3.77	47.50 ± 3.78	45.40 ± 3.96	45.59 ± 3.76	45.72 ± 3.70	45.79 ± 3.48	45.38 ± 3.62	44.53 ± 3.58	45.60 ± 3.87	
al-al/se-sn (nasal index) (nasal width in relation to nasal height)	Boys	AnthrInd	69.15 ± 8.14	**71.84 ± 8.15**	69.62 ± 5.12	**70.29 ± 6.77**	**70.44 ± 7.46**	**69.11 ± 6.76**	**68.81 ± 6.49**	**70.19 ± 6.94**	69.82 ± 6.82	69.97 ± 8.31	68.86 ± 8.17	>0.05
		PhotoInd	74.45 ± 5.32	**71.56 ± 6.10**	71.79 ± 5.04	**69.83 ± 5.34**	**72.77 ± 6.32**	**68.82 ± 5.94**	**70.35 ± 5.56**	**71.95 ± 5.86**	71.00 ± 6.38	71.21 ± 6.39	70.44 ± 7.04	
	Girls	AnthrInd	67.37 ± 7.4	68.96 ± 6.69	69.27 ± 6.34	67.89 ± 6.41	66.85 ± 5.55	67.19 ± 6.15	65.24 ± 5.06	64.45 ± 7.34	65.65 ± 6.11	**69.61 ± 8.88**	**66.90 ± 7.51**	>0.05
		PhotoInd	74.23 ± 6.05	74.99 ± 5.75	73.78 ± 5.20	72.32 ± 4.43	75.42 ± 5.86	73.08 ± 5.52	72.86 ± 5.23	71.75 ± 5.84	68.49 ± 5.70	**69.95 ± 6.29**	**67.90 ± 5.77**	

(*Continued*)

Table 4. Continued.

Index		Age	10	11	12	13	14	15	16	17	18	19	20	*p*-value
al-al/se-sto (nasal width in relation to physiognomic upper facial height)	Boys	AnthrInd	46.39 ± 8.15	47.33 ± 5.19	47.03 ± 3.64	47.19 ± 4.16	48.30 ± 3.80	**48.01 ± 7.56**	46.95 ± 3.98	48.35 ± 6.19	47.36 ± 4.18	48.21 ± 4.74	47.68 ± 4.97	>0.05
		PhotoInd	51.66 ± 2.99	50.14 ± 3.94	50.48 ± 3.72	50.36 ± 3.3	51.84 ± 3.64	**49.63 ± 3.90**	50.8 ± 3.60	51.43 ± 4.06	50.21 ± 3.94	50.71 ± 4.17	50.39 ± 4.43	
	Girls	AnthrInd	45.42 ± 4.34	46.16 ± 4.00	46.32 ± 3.75	46.48 ± 4.11	46.36 ± 3.61	46.67 ± 3.86	45.24 ± 2.80	44.85 ± 4.61	45.76 ± 4.06	48.22 ± 5.54	46.44 ± 4.25	>0.05
		PhotoInd	51.71 ± 3.48	52.77 ± 3.66	52.51 ± 3.10	52.19 ± 3.17	53.33 ± 3.73	52.58 ± 3.61	52.29 ± 2.92	51.45 ± 4.11	49.69 ± 3.73	50.74 ± 4.31	48.93 ± 3.76	
al-al/se-gn (nasal width in relation to morphological facial height)	Boys	AnthrInd	28.86 ± 2.95	28.84 ± 2.11	29.47 ± 2.27	29.73 ± 2.55	29.92 ± 2.41	29.67 ± 2.83	29.90 ± 2.43	30.02 ± 2.82	29.86 ± 2.51	30.12 ± 2.96	29.83 ± 3.24	>0.05
		PhotoInd	32.64 ± 2.02	31.85 ± 2.06	31.91 ± 2.52	31.52 ± 2.10	32.49 ± 2.26	31.58 ± 2.69	31.95 ± 2.10	32.34 ± 2.62	31.59 ± 2.34	31.73 ± 2.56	31.70 ± 3.50	
	Girls	AnthrInd	29.42 ± 2.81	29.96 ± 2.48	30.04 ± 2.53	30.35 ± 2.50	30.39 ± 2.38	30.42 ± 2.76	29.54 ± 1.74	29.19 ± 2.71	29.56 ± 2.27	30.51 ± 3.17	29.10 ± 2.71	>0.05
		PhotoInd	32.73 ± 2.22	33.52 ± 2.31	33.34 ± 2.05	33.42 ± 2.04	34.00 ± 2.57	33.18 ± 2.22	32.74 ± 1.68	32.58 ± 2.53	32.22 ± 2.56	32.15 ± 2.75	30.99 ± 2.14	

In bold—no statistically significant difference between indices calculated from direct anthropometry and from photographs ($p \geq 0.05$), therefore, these methods could be used interchangeably.
AnthrInd—antropometrically determined indices.
PhotoInd—indices determined from photographs.
statistically significant difference between boys and girls' indices calculated from direct anthropometry measurements ($p < 0.05$).

showed a strong sexual dimorphism throughout all time periods, except at the age of 10, and was statistically significantly higher in boys compared to girls ($p < 0.05$), indicating that boys had relatively wider noses compared to labial fissure width.

Nasal index showed a tendency to be larger in boys compared to girls (indicating a relatively wider nose in boys) although the difference was not statistically significant in all age groups. It showed large variations in boys—with a peak value at 11 years, and a slight decrease from 14 to 17 years of age. At the beginning of adolescence, the noses of boys became much wider rather than longer, however, in the middle of adolescence they grew more vertically than horizontally. Linear regression showed no statistically significant gradual tendency in the nasal index in boys ($p > 0.05$)—the changes of this index were highly fluctuating. The standard deviation of the nasal index in boys from 10 to 20 years of age was the largest of all indices (SD = 7.27) indicating very high variability. At the end of adolescence the nasal proportions of boys evened and at 20 years of age this index did not differ significantly from its value at 10 years of age ($p > 0.05$). In contrast to boys, linear regression showed that the nasal index in girls gradually decreased with age ($p < 0.05$).

Dynamics of facial indices containing labial fissure width calculated using direct anthropometry measurements

Intercanthal width in relation to labial fissure width (en-en/ch-ch) decreased in both sexes from 10 to 20 years of age ($p < 0.001$), although a significant sexual dimorphism for this index was not obvious in all age groups (Table 5). This finding reflects a rapid widening of the lips relative to the eye area—in boys it was even more obvious than in girls. Labial fissure width relative to biocular width (ch-ch/ex-ex) and to interpupillary distance (ch-ch/pu-pu) increased gradually with small peaks in boys at 12 and 17 years of age and in girls at 14 and 16 years of age. It was significantly larger at 20 years than at 10 in both boys and girls ($p < 0.05$). Indices containing labial fissure width relative to eye parameter dynamics showed that lips became wider at a faster rate than the eye area in both sexes during the investigated time period. Labial fissure width in relation to physiognomic upper facial height (ch-ch/se-sto) and to morphological facial height (ch-ch/se-gn) were significantly larger in girls in almost all age groups ($p < 0.05$), which shows that the faces of boys were relatively longer with narrower lips. In boys, labial fissure width in relation to physiognomic upper facial height (ch-ch/se-sto) decreased between the ages of 11 and 15 (during this time period their lips widened more slowly than the upper part of their face grew vertically). In girls, it increased from 12 to 19 years of age. However, the proportion of labial fissure width in relation to physiognomic upper facial height (ch-ch/se-sto) was almost the same at 10 and 20 years of age in both sexes ($p > 0.05$). This showed that although there were some growth dynamics in mid-adolescence, facial proportions eventually stabilised. The linear regression analysis also did not show clear trends in the dynamics of labial fissure width in relation to morphological and physiognomic facial heights (ch-ch/se-gn and ch-ch/se-sto) from 10 to 20 years of age.

Labial fissure width in relation to bigonial width (ch-ch/go-go) in boys increased peaking between the ages of 12 and 14, however, its value at the age of 20 was almost the same as at the age of 10 ($p > 0.05$). In most age groups, it was statistically significantly higher in the girls' group ($p < 0.05$), reflecting a wider jaw in boys compared to the lips.

Dynamics of facial indices containing the main transverse parameters calculated using direct anthropometry measurements

Facial index (se-gn/zy-zy) was significantly larger in boys compared to girls in most age groups ($p < 0.05$), meaning that the faces of boys were relatively longer. It gradually increased in boys and girls with small peaks in boys of around 12 and 14–15 years of age. This suggests that the faces of boys grew at different rates in height and width at different times, while the faces of girls grew more evenly.

In terms of the indices including bizygomatic width, the linear regression analysis showed gradual trends in the dynamics of almost all of them. Interpupillary distance in relation to bizygomatic width

Table 5. Means and standard deviations of indices containing labial fissure width from 10 to 20 years of age (*p*-value in the last column shows the comparison of the means of anthropometrically determined indices between the 10- and 20-year-old age groups for boys and girls separately).

Index	Age		10	11	12	13	14	15	16	17	18	19	20	*p*-value
en-en/ch-ch (intercanthal width in relation to labial fissure width)	Boys	AnthrInd	**69.63 ± 6.71**	73.23 ± 7.24	72.70 ± 7.84	69.63 ± 9.11	67.56 ± 6.34	**67.28 ± 7.72**	66.81 ± 6.30	**64.15 ± 6.53**	64.41 ± 5.98	**62.44 ± 6.07**	63.57 ± 6.73	<0.001
		PhotoInd	**68.91 ± 5.09**	68.45 ± 7.54	69.80 ± 7.34	65.82 ± 6.38	65.16 ± 5.79	**64.47 ± 7.19**	63.79 ± 6.25	**62.29 ± 6.33**	62.05 ± 6.22	**60.98 ± 5.81**	61.21 ± 6.32	
	Girls	AnthrInd	**69.74 ± 7.92**	70.17 ± 7.55	69.70 ± 7.20	**67.22 ± 6.35**	66.45 ± 6.26	**66.63 ± 8.15**	**64.09 ± 7.42**	**64.62 ± 6.09**	**65.14 ± 6.40**	**64.82 ± 6.72**	**64.91 ± 5.99**	<0.001
		PhotoInd	**69.02 ± 7.11**	67.61 ± 6.93	66.50 ± 7.24	**64.73 ± 5.56**	63.03 ± 5.41	**64.01 ± 6.35**	**62.53 ± 6.17**	**63.46 ± 5.62**	**63.74 ± 5.55**	**63.14 ± 5.29**	**63.53 ± 4.93**	
ch-ch/pu-pu (labial fissure width in relation to interpupillary distance)	Boys	AnthrInd	**77.27 ± 6.96**	**75.40 ± 6.3**	**74.2 ± 5.09**	**76.22 ± 7.26**	**77.48 ± 6.20**	**78.74 ± 5.88**	**77.91 ± 5.40**	**80.04 ± 6.33**	**79.37 ± 4.92**	**80.33 ± 4.26**	**79.74 ± 5.54**	<0.05
		PhotoInd	**76.85 ± 4.26**	**76.79 ± 5.44**	**75.04 ± 6.14**	**77.61 ± 5.63**	**79.00 ± 5.63**	**79.49 ± 5.41**	**78.98 ± 5.68**	**80.77 ± 6.38**	**79.98 ± 4.94**	**81.47 ± 5.37**	**81.01 ± 5.14**	
	Girls	AnthrInd	**76.66 ± 7.42**	**76.57 ± 6.12**	**76.74 ± 6.10**	**78.44 ± 6.12**	**79.88 ± 6.49**	**78.92 ± 6.33**	**81.34 ± 6.43**	**81.48 ± 5.39**	**80.62 ± 5.79**	**79.81 ± 6.09**	**79.32 ± 5.13**	<0.05
		PhotoInd	**76.81 ± 6.21**	**77.81 ± 5.69**	**78.35 ± 6.14**	**79.95 ± 5.03**	**81.94 ± 5.61**	**80.14 ± 5.40**	**82.16 ± 5.14**	**81.39 ± 5.69**	**79.78 ± 5.47**	**80.42 ± 5.15**	**79.03 ± 4.58**	
ch-ch/ex-ex (labial fissure width in relation to biocular width)	Boys	AnthrInd	**51.81 ± 3.33**	**51.07 ± 3.83**	**50.26 ± 3.90**	51.04 ± 4.55	51.73 ± 4.87	**53.66 ± 3.89**	**53.70 ± 3.82**	**54.95 ± 4.25**	**54.87 ± 3.44**	**55.37 ± 3.34**	**55.55 ± 4.01**	<0.001
		PhotoInd	**52.37 ± 2.93**	**52.19 ± 3.60**	**51.20 ± 4.03**	52.80 ± 3.48	54.59 ± 3.50	**54.34 ± 3.76**	**54.15 ± 3.67**	**55.68 ± 3.85**	**54.56 ± 3.49**	**55.75 ± 3.40**	**55.86 ± 3.29**	
	Girls	AnthrInd	50.82 ± 4.33	51.48 ± 3.80	51.60 ± 3.32	52.77 ± 3.67	53.07 ± 4.28	52.67 ± 3.96	54.04 ± 4.01	53.93 ± 3.64	**53.65 ± 3.84**	**55.10 ± 4.00**	**54.24 ± 3.61**	<0.001
		PhotoInd	53.14 ± 3.98	53.76 ± 3.69	54.03 ± 3.93	54.95 ± 3.11	56.63 ± 3.90	55.03 ± 3.34	56.05 ± 3.09	55.49 ± 3.73	**54.02 ± 3.43**	**55.04 ± 3.26**	**54.12 ± 3.03**	
ch-ch/go-go (labial fissure width in relation to bigonial width)	Boys	AnthrInd	44.66 ± 4.40	**43.38 ± 3.71**	**43.39 ± 3.46**	**44.14 ± 5.05**	**45.69 ± 5.03**	**45.31 ± 4.12**	**44.76 ± 3.20**	**45.47 ± 3.69**	45.62 ± 3.53	46.11 ± 3.17	45.75 ± 3.59	>0.05
		PhotoInd	42.96 ± 2.46	**43.36 ± 2.78**	**42.79 ± 2.95**	**43.37 ± 2.76**	**44.74 ± 2.95**	**44.09 ± 3.30**	**43.84 ± 2.79**	**45.27 ± 3.12**	43.88 ± 2.94	44.19 ± 3.45	43.45 ± 2.76	
	Girls	AnthrInd	46.60 ± 4.39	46.08 ± 3.83	45.99 ± 3.69	**47.29 ± 3.94**	**47.90 ± 3.81**	47.94 ± 4.36	49.69 ± 3.92	49.17 ± 3.58	48.77 ± 3.79	46.65 ± 3.15	46.43 ± 2.90	>0.05
		PhotoInd	43.31 ± 3.24	44.18 ± 3.15	44.71 ± 2.76	**45.82 ± 3.22**	**46.18 ± 3.14**	44.96 ± 3.09	46.22 ± 3.60	45.86 ± 3.09	42.85 ± 3.22	43.15 ± 2.74	42.89 ± 2.41	
ch-ch/se-gn (labial fissure width in relation to morphological facial height)	Boys	AnthrInd	**42.72 ± 4.43**	**41.02 ± 3.95**	**40.40 ± 3.29**	**41.22 ± 4.38**	40.84 ± 3.09	**41.22 ± 3.60**	**41.55 ± 3.52**	**41.95 ± 4.33**	**41.79 ± 3.13**	**42.31 ± 2.92**	**42.21 ± 3.89**	>0.05
		PhotoInd	**42.99 ± 2.64**	**42.36 ± 3.18**	**41.64 ± 3.56**	**41.25 ± 2.96**	42.43 ± 2.64	**41.82 ± 3.77**	**41.98 ± 3.28**	**42.82 ± 3.51**	**41.76 ± 2.91**	**42.67 ± 2.87**	**42.69 ± 4.24**	
	Girls	AnthrInd	**43.76 ± 4.68**	**44.34 ± 4.14**	**43.88 ± 3.63**	**44.60 ± 4.11**	**45.14 ± 4.07**	**45.18 ± 4.19**	**45.95 ± 3.82**	**46.05 ± 3.57**	**45.68 ± 3.45**	**44.88 ± 3.98**	**43.23 ± 3,72**	>0.05
		PhotoInd	**43.30 ± 3.86**	**44.80 ± 3.73**	**44.25 ± 3.45**	**44.73 ± 3.35**	**46.05 ± 3.54**	**44.94 ± 2.88**	**45.61 ± 3.32**	**45.67 ± 3.54**	**44.62 ± 3.99**	**44.73 ± 3.40**	**43.15 ± 2.60**	
ch-ch/se-sto (labial fissure width in relation to physiognomic upper facial height)	Boys	AnthrInd	**66.74 ± 12.78**	**67.34 ± 8.25**	**64.47 ± 5.40**	**65.48 ± 7.44**	**65.96 ± 5.52**	**66.70 ± 10.14**	**65.24 ± 5.64**	**67.45 ± 7.65**	**66.25 ± 5.00**	**67.71 ± 4.46**	**67.51 ± 6.43**	>0.05
		PhotoInd	**68.07 ± 4.41**	**66.67 ± 5.61**	**65.88 ± 5.52**	**65.90 ± 4.61**	**67.74 ± 4.84**	**65.72 ± 5.41**	**66.75 ± 5.50**	**68.08 ± 5.41**	**66.33 ± 4.66**	**68.21 ± 5.14**	**67.90 ± 5.50**	
	Girls	AnthrInd	**67.63 ± 7.99**	68.31 ± 6.59	67.66 ± 5.29	**68.31 ± 6.43**	68.86 ± 6.42	**69.34 ± 6.31**	70.37 ± 5.91	**70.74 ± 6.04**	70.70 ± 6.00	**70.93 ± 7.10**	**68.99 ± 3.03**	>0.05
		PhotoInd	**68.40 ± 6.12**	70.53 ± 5.99	69.70 ± 5.40	**69.88 ± 5.44**	72.22 ± 5.15	**71.22 ± 4.66**	72.80 ± 5.02	**72.13 ± 5.95**	68.73 ± 4.94	**70.65 ± 6.04**	**68.12 ± 4.64**	

In bold—no statistically significant difference between indices calculated from direct anthropometry and from photographs ($p \geq 0.05$), therefore, these methods could be used interchangeably.
AnthrInd—antropometrically determined indices.
PhotoInd—indices determined from photographs.
statistically significant difference between boys and girls' indices calculated from direct anthropometry measurements ($p < 0.05$).

(pu-pu/zy-zy) and intercanthal width in relation to bizygomatic width (en-en/zy-zy) gradually decreased across age, meaning that the cheekbones grew in width faster than the inner corners of palpebral fissure. The physiognomic upper facial height in relation to bizygomatic width (se-sto/zy-zy) in girls could be an exception -—this index tended to be stable—- the middle of the face in girls grew vertically at a similar rate as the cheekbones widened. Interpupillary distance in relation to bizygomatic width (pu-pu/zy-zy) was mostly larger in girls ($p < 0.05$), meaning the cheekbones were wider in relation to the width between pupils in boys.

Interpupillary distance in relation to bigonial width (pu-pu/go-go) and to intercanthal width in relation to bigonial width (en-en/go-go) slightly decreased showing that the jaw became relatively wider than the distance between the inner corners of palpebral fissure and between the pupils. These indices were larger in girls in most age groups ($p < 0.05$) which showed relatively wider jaws in boys in relation to the eye area. In contrast, biocular width relative to bigonial width (ex-ex/go-go) showed noticeable fluctuation. The value of this index was significantly larger in girls as well ($p < 0.05$).

The physiognomic upper facial height in relation to bigonial width (se-sto/go-go) slightly increased with age in boys. However, the linear regression analysis showed no linear association with age in girls ($p > 0.05$), even though the index value was smaller at 20 than at 10 years of age ($p < 0.05$). Index values were significantly larger in girls in most age groups until 18 years of age, however, later the boys' index values became larger. These results show that the faces of girls were slightly longer relative to jaw width in early adolescence, while the faces of boys reached this proportionality in late adolescence.

Bigonial width in relation to morphological facial height (go-go/se-gn) in boys decreased between the ages of 12 and 16 years, probably due to a relatively larger increase in upper facial height during mid-adolescence, and was smaller at 20 than at 10 years of age ($p < 0.01$). There was a general trend of decrease in girls as well.

Lastly, the index between mandibular and zygomatic widths (go-go/zy-zy) remained stable across ages—the face became broader evenly and linear regression analysis showed no significant linear association with age. The values of the index did not significantly differ between 10 and 20 years of age in either of the sexes ($p > 0.05$). This finding was supported by the linear regression analysis—it showed no significant linear association with age. This index demonstrated low variability (SD = 3.60 in boys, SD = 3.04 in girls). It was significantly larger in boys aged 10, 11, 15, 16 and 17 years ($p < 0.05$)—the jaw of boys was relatively wider in comparison with the cheekbones compared to the same parameters of girls.

General trends in the dynamics of facial indices calculated using direct anthropometric measurements

The most stable indices

Indices that remain stable from 10 to 20 years of age play an important role in determining facial proportions that do not rapidly change. This study revealed that more indices remained stable in girls than in boys, however, there were indices that were relatively stable across ages in both sexes. The nose became wider at almost the same rate as the face grew vertically. Bigonial width in relation to bizygomatic width showed low variability—the main transverse parameters grew evenly when compared to each other. The distance between the inner corners of palpebral fissure relative to biocular width remained stable in girls which means that the eye region grew evenly.

Gradually increased indices

The indices that gradually increased were determined. The faces elongated faster than the widths of cheekbones and the eyes. Labial fissure width increased relatively more than jaw width and eye parameters. This was reflected by the physiognomic upper facial height and labial fissure width relative to eye parameters, labial fissure width relative to bigonial width and the indices which included bizygomatic width relative to facial heights.

Gradually decreased indices

The indices that gradually decreased are also significant for facial growth modelling. The eye region grew slower when compared to transverse facial parameters and nasal width. Gradually decreasing indices included eye parameters in relation to facial heights and intercanthal width in relation to nasal width.

The most variable indices

We determined the most variable indices—the changes of these proportions are complicated to predict. The nasal index in boys showed the most variability. The nasal proportions stabilised at the end of adolescence, however, they varied during mid-adolescence with the nose widening substantially up to 11 years, then growing vertically until 16 years of age and then widening again. Labial fissure width relative to nasal width and the physiognomic upper facial height in boys also largely varied. From 10 to 12 years of age the nose widened relatively more than the lips. However, from 15 to 20 years of age, the lips became relatively wider than the nose.

Comparison of indices containing eye parameters determined by two methods

The indices containing the eye parameters revealed mostly no significant differences between the values calculated from direct anthropometry and from photographs in both sexes (Table 7).

Interpupillary distance in relation to morphological facial height (pu-pu/se-gn) showed no significant difference across all age groups between the values calculated from the two methods in both boys and girls. It showed the best consistency out of all indices containing eye parameters. Physiognomic upper facial height in relation to biocular width (se-sto/ex-ex) and interpupillary distance in relation to the physiognomic upper facial height (pu-pu/se-sto) also showed excellent consistency between the two methods in boys—they did not differ across the age groups. In girls they did not differ between the values calculated from direct anthropometry and from photographs for most age groups.

Other indices containing eye parameters also showed a high level of consistency between the two methods. Intercanthal distance in relation to physiognomic upper facial height (en-en/se-sto) did not differ between the two methods of measurement during almost the entire time period in girls. Intercanthal width in relation to morphological facial height and to biocular width (en-en/se-gn and en-en/ex-ex) did not differ for most age groups in either of the sexes.

Interpupillary distance in relation to biocular width (pu-pu/ex-ex) did not differ between the two methods in all age groups except for 14 and 18 years of age in boys. In girls it showed lower consistency—it differed in all age periods except for 19 and 20 years of age.

Comparison of indices containing nasal width and nasal height determined by two methods

In boys, nasal index (al-al/se-sn) and nasal height in relation to bigonial width (se-sn/go-go) showed the highest consistency between the indices calculated by means of the two methods (Table 4). Nasal index did not differ in six age groups of boys. In contrast, it differed between the values obtained using direct anthropometry and photographic analysis in almost all age groups in girls. Nasal height in relation to bigonial width (se-sn/go-go) did not differ in seven age groups of boys but differed in all groups in girls. The highest consistency between the two methods was observed in intercanthal width in relation to nasal height (en-en/se-sn) in girls and this index differed in all groups of boys.

The indices containing nasal width relative to interpupillary distance (al-al/pu-pu), morphological facial height (al-al/se-gn), labial fissure width (al-al/ch-ch), intercanthal width (en-en/al-al) and biocular width (al-al/ex-ex) differed between values obtained using direct anthropometry and photographic analysis in all age groups of both boys and girls.

In general, the consistency of indices containing nasal parameters calculated using two different methods was higher in boys than in girls.

Comparison of indices containing labial fissure width determined by two methods

The indices containing labial fissure width showed very high consistency between the values calculated using direct anthropometry and using photographic analysis across age groups in both boys and girls

(Table 8). Labial fissure width in relation to interpupillary distance (ch-ch/pu-pu) showed the best agreement and can be used interchangeably between the two methods over the entire time period from 10 to 20 years of age in both sexes. Labial fissure width in relation to morphological facial height (ch-ch/se-gn) also showed a high consistency between the two methods as it did not differ in all age groups of girls but differed only in 14-year-old boys. Labial fissure width in relation to the physiognomic upper facial height (ch-ch/se-sto) did not differ between values calculated using direct anthropometry and photographic analysis over all time periods for boys and did not differ in most age groups of girls.

Other indices containing labial fissure width showed lower but still substantial agreement. Intercanthal width in relation to labial fissure width (en-en/ch-ch) showed higher consistency in girls than in boys. Labial fissure width in relation to biocular width (ch-ch/ex-ex) showed higher consistency between the two methods for boys.

Comparison of indices containing bizygomatic and bigonial widths determined by two methods

In boys, the agreement between the indices calculated using direct anthropometry and photographs which contained bigonial width was low but higher than in girls (Table 6). The highest correlation of indices containing bigonial width between the values calculated using the two methods in boys was for interpupillary distance in relation to bigonial width (pu-pu/go-go) and the physiognomic upper facial height in relation to bigonial width (se-sto/go-go)—neither of them differed in the 11, 15, and 17 years of age groups.

All indices containing bigonial width differed in girls between the two methods. An exception could be labial fissure width in relation to bigonial width (ch-ch/go-go), however, this index was attributed to indices containing labial fissure width group according to the parameter which was in the numerator (Tables 5 and 8).

All indices containing bizygomatic width, including facial index (se-gn/zy-zy), showed significant differences between direct anthropometry and photographic analysis in all age groups and both sexes (Table 6).

Discussion

This study analysed the dynamics of facial indices from 10 to 20 years of age. In addition, it compared facial indices calculated using direct facial anthropometry and photoanthropometry.

Dynamics of anthropometrically determined facial indices

This study showed that the eye area grew evenly when compared to other facial parameters. Another study investigated the parameters of the eyes of children in Thailand from birth to 19 years including intercanthal width in relation to biocular width (Jullabussapa et al. 2020). This index was found to remain stable, which was consistent with our results for girls. Our study showed that in line with the increasing facial height the eyes became relatively smaller. It is known that the length of the face increases twice its width during puberty, while the total dimensions of eyes are the most stable (Bishara et al. 1995).

Interestingly, the nasal index (the ratio of nasal width to nasal height) dynamics suggested different growth patterns of the nose between sexes. It is consistent with previous findings that the nasal region starts to show high sexual dimorphism in puberty (Kesterke et al. 2016). One Brazilian study found that the nose widened primarily between 10 and 14 years of age, which was similar to our results, but no increase in the nasal height was observed later in adolescence, which was evident in our study (Machado et al. 2017). Another investigation suggested that the nasal bridge length spurt for girls could be at the age of 13.1 years, and for boys—at 14.7 years (van der Heijden et al. 2008). These findings were largely consistent with those of our study. Iranian authors analysed the growth of the nasal region in 12–15 year-old boys (Jahanbin et al. 2012). The Iranian population nasal index was higher in all age groups compared to our study. This shows that the noses of Iranian boys were relatively wider but shorter than those of Lithuanian teenage boys.

Table 6. Means and standard deviations of indices containing main transverse facial parameters of adolescents from 10 to 20 years of age (*p*-value in the last column shows the comparison of the means of anthropometrically determined indices between the 10- and 20-year-old age groups for boys and girls separately).

Index	Age		10	11	12	13	14	15	16	17	18	19	20	*p*-value
se-gn/zy-zy (morphological facial height in relation to bizygomatic width)	Boys	AnthrInd	78.51 ± 4.48	79.05 ± 4.09	80.78 ± 5.66	79.84 ± 5.04	82.83 ± 3.99	82.62 ± 5.50	80.36 ± 3.78	81.85 ± 5.31	81.20 ± 4.48	81.00 ± 5.44	81.14 ± 6.24	<0.001
		PhotoInd	89.63 ± 3.97	89.65 ± 4.08	91.09 ± 4.22	94.14 ± 4.78	95.15 ± 4.61	94.76 ± 5.35	94.77 ± 4.80	96.13 ± 4.41	96.78 ± 5.39	95.52 ± 4.84	95.30 ± 6.76	
	Girls	AnthrInd	77.81 ± 4.37	76.46 ± 4.65	77.93 ± 4.16	78.49 ± 4.26	78.51 ± 4.07	77.72 ± 4.63	78.97 ± 3.58	78.80 ± 4.03	78.86 ± 4.27	77.23 ± 3.99	79.37 ± 4.84	<0.05
		PhotoInd	90.25 ± 4.56	86.81 ± 4.53	88.95 ± 4.24	90.49 ± 3.76	87.61 ± 3.61	88.42 ± 4.06	89.79 ± 3.79	89.01 ± 4.73	89.02 ± 6.28	89.72 ± 4.72	93.32 ± 14.91	
en-en/zy-zy (intercanthal width in relation to bizygomatic width)	Boys	AnthrInd	23.14 ± 1.56	23.55 ± 1.69	23.58 ± 2.42	22.65 ± 2.06	22.72 ± 1.57	22.73 ± 2.11	22.16 ± 1.51	21.83 ± 1.87	21.75 ± 1.89	21.29 ± 1.90	21.60 ± 2.11	<0.001
		PhotoInd	26.46 ± 1.78	25.85 ± 2.39	26.28 ± 1.87	25.43 ± 2.07	26.19 ± 1.72	25.36 ± 2.35	25.22 ± 1.90	25.48 ± 2.02	24.94 ± 2.13	24.73 ± 1.96	24.72 ± 2.37	
	Girls	AnthrInd	23.50 ± 1.99	23.58 ± 1.91	23.67 ± 1.88	23.38 ± 1.90	23.40 ± 1.92	23.18 ± 2.0	23.09 ± 2.02	23.32 ± 1.85	23.33 ± 1.85	22.31 ± 1.84	22.13 ± 1.84	<0.001
		PhotoInd	26.78 ± 2.21	26.09 ± 1.86	26.01 ± 2.24	26.08 ± 1.86	25.30 ± 1.69	25.32 ± 2.04	25.48 ± 1.99	25.64 ± 1.80	25.13 ± 1.82	25.22 ± 1.96	25.50 ± 4.19	
en-en/go-go (intercanthal width in relation to bigonial width)	Boys	AnthrInd	30.89 ± 2.39	31.60 ± 2.50	31.42 ± 3.16	30.47 ± 3.34	30.73 ± 3.36	30.33 ± 3.26	29.81 ± 2.55	29.03 ± 2.54	29.31 ± 2.77	28.74 ± 2.86	28.96 ± 2.77	<0.001
		PhotoInd	29.56 ± 2.25	29.61 ± 3.13	29.72 ± 2.25	28.46 ± 2.50	29.06 ± 2.16	28.30 ± 2.74	27.88 ± 2.34	28.08 ± 2.31	27.13 ± 2.33	26.84 ± 2.27	26.53 ± 2.63	
	Girls	AnthrInd	32.28 ± 3.01	32.17 ± 2.83	31.90 ± 2.74	31.68 ± 3.00	31.70 ± 2.71	31.74 ± 3.02	31.69 ± 3.09	31.68 ± 2.80	31.64 ± 2.61	30.13 ± 2.66	30.04 ± 2.24	<0.001
		PhotoInd	29.77 ± 2.61	29.74 ± 2.47	29.74 ± 2.47	29.58 ± 2.44	29.01 ± 2.07	28.70 ± 2.62	28.79 ± 2.43	29.00 ± 2.09	27.21 ± 2.07	27.18 ± 2.07	27.21 ± 2.22	
pu-pu/zy-zy (interpupillary distance in relation to bizygomatic width)	Boys	AnthrInd	43.32 ± 1.77	42.95 ± 2.14	43.92 ± 2.64	43.09 ± 1.92	43.65 ± 1.60	43.17 ± 2.00	42.79 ± 1.73	42.76 ± 2.00	42.69 ± 1.91	42.55 ± 1.52	42.81 ± 2.28	>0.05
		PhotoInd	50.11 ± 2.12	49.46 ± 2.68	50.52 ± 2.29	50.03 ± 2.43	51.14 ± 2.48	49.76 ± 2.54	50.34 ± 2.39	50.95 ± 2.49	50.50 ± 2.67	50.02 ± 2.53	50.06 ± 2.86	
	Girls	AnthrInd	44.36 ± 2.26	44.18 ± 1.74	44.54 ± 2.17	44.56 ± 2.02	44.34 ± 2.47	44.41 ± 1.90	44.58 ± 1.61	44.48 ± 1.96	44.64 ± 1.83	43.38 ± 2.11	43.15 ± 1.84	<0.001
		PhotoInd	50.84 ± 2.50	49.91 ± 2.02	50.24 ± 2.57	50.60 ± 2.29	49.21 ± 2.06	49.60 ± 2.26	49.80 ± 1.95	49.89 ± 2.02	49.64 ± 2.23	49.85 ± 2.26	50.92 ± 7.82	
pu-pu/go-go (interpupillary distance in relation to bigonial width)	Boys	AnthrInd	57.83 ± 3.16	**57.62 ± 3.46**	58.54 ± 3.68	57.92 ± 3.57	58.97 ± 4.30	**57.58 ± 3.62**	57.54 ± 3.35	**56.88 ± 3.09**	57.51 ± 3.22	57.44 ± 3.26	57.44 ± 3.50	>0.05
		PhotoInd	55.96 ± 2.83	**56.63 ± 4.02**	57.14 ± 2.81	56.00 ± 3.11	56.74 ± 3.31	**55.51 ± 3.01**	55.63 ± 3.24	**56.17 ± 3.13**	54.92 ± 2.88	54.29 ± 3.40	53.75 ± 3.59	
	Girls	AnthrInd	60.91 ± 3.59	60.25 ± 3.07	60.01 ± 3.24	60.37 ± 3.56	60.09 ± 4.03	60.81 ± 3.63	61.17 ± 3.37	60.40 ± 3.11	60.57 ± 3.61	58.59 ± 3.60	58.60 ± 2.75	<0.001
		PhotoInd	56.52 ± 3.40	56.89 ± 3.44	57.21 ± 3.20	57.38 ± 3.33	56.44 ± 3.11	56.20 ± 3.38	56.28 ± 2.97	56.43 ± 2.73	53.75 ± 2.83	53.73 ± 2.89	54.35 ± 2.83	
ex-ex/go-go (biocular width in relation to bigonial width)	Boys	AnthrInd	**84.33 ± 11.39**	**85.00 ± 4.96**	86.59 ± 7.00	86.81 ± 10.06	89.07 ± 13.01	84.67 ± 8.26	83.49 ± 4.79	82.84 ± 4.60	83.25 ± 5.52	83.40 ± 5.24	82.48 ± 5.40	>0.05
		PhotoInd	**82.12 ± 4.09**	**83.28 ± 5.47**	83.71 ± 3.59	82.23 ± 3.98	82.04 ± 4.03	81.20 ± 4.18	81.10 ± 4.30	81.38 ± 3.68	80.50 ± 3.79	79.29 ± 4.41	77.89 ± 4.55	
	Girls	AnthrInd	91.76 ± 5.32	89.59 ± 4.90	89.16 ± 4.70	89.73 ± 6.07	90.52 ± 7.17	91.12 ± 6.03	92.05 ± 5.01	91.25 ± 4.21	90.99 ± 4.88	84.83 ± 4.89	85.73 ± 4.59	<0.001
		PhotoInd	81.63 ± 4.47	82.30 ± 4.63	82.91 ± 4.40	83.43 ± 4.28	81.65 ± 4.23	81.77 ± 4.38	82.44 ± 4.00	82.73 ± 3.53	79.33 ± 3.77	78.47 ± 3.67	79.33 ± 3.75	
go-go/zy-zy (bigonial width in relation to bizygomatic width)	Boys	AnthrInd	75.01 ± 2.94	74.64 ± 2.87	75.16 ± 4.23	74.57 ± 4.03	74.27 ± 4.10	75.11 ± 3.28	74.49 ± 3.03	75.28 ± 3.24	74.37 ± 3.89	74.22 ± 3.31	74.67 ± 4.01	>0.05
		PhotoInd	89.62 ± 2.55	87.47 ± 2.53	88.46 ± 2.36	89.40 ± 2.12	90.21 ± 2.65	89.69 ± 2.44	90.57 ± 2.29	90.79 ± 2.99	91.97 ± 2.61	92.25 ± 3.23	93.24 ± 3.26	
	Girls	AnthrInd	72.90 ± 2.35	73.42 ± 2.90	74.28 ± 2.57	73.95 ± 3.51	73.90 ± 3.40	73.18 ± 3.53	73.01 ± 3.12	73.74 ± 3.06	73.84 ± 3.30	74.15 ± 2.80	73.70 ± 3.11	>0.05
		PhotoInd	90.05 ± 3.06	87.86 ± 2.94	87.88 ± 2.62	88.27 ± 2.50	87.29 ± 2.60	88.36 ± 2.69	88.59 ± 2.60	88.47 ± 2.15	92.42 ± 2.56	92.85 ± 2.62	93.71 ± 13.40	
se-sto/zy-zy (physiognomic upper facial height in relation to bizygomatic width)	Boys	AnthrInd	49.16 ± 3.46	48.40 ± 4.09	50.60 ± 3.02	50.31 ± 3.18	51.33 ± 2.79	51.45 ± 4.48	51.18 ± 2.42	50.99 ± 3.82	51.23 ± 2.98	50.57 ± 2.85	50.73 ± 3.59	<0.01
		PhotoInd	56.63 ± 2.77	57.03 ± 3.25	57.57 ± 2.83	58.94 ± 3.40	59.68 ± 3.54	60.26 ± 3.33	59.65 ± 3.41	60.44 ± 2.77	60.94 ± 3.69	59.82 ± 7.87	59.85 ± 4.23	
	Girls	AnthrInd	50.42 ± 3.22	49.67 ± 3.38	50.53 ± 2.72	51.29 ± 3.07	51.50 ± 3.27	50.62 ± 2.88	51.60 ± 2.83	51.35 ± 3.13	51.02 ± 3.23	48.97 ± 3.37	49.74 ± 3.04	>0.05
		PhotoInd	57.13 ± 2.88	55.18 ± 3.49	56.49 ± 3.04	57.96 ± 2.84	55.87 ± 2.87	55.82 ± 2.93	56.27 ± 3.04	56.39 ± 3.18	57.69 ± 3.70	56.87 ± 3.42	59.18 ± 9.73	

(*Continued*)

Table 6. Continued.

Index	Age		10	11	12	13	14	15	16	17	18	19	20	*p*-value
se-sto/go-go (physiognomic upper facial height in relation to bigonial width)	Boys	AnthrInd	65.62 ± 4.86	**64.94 ± 6.04**	67.47 ± 4.69	67.61 ± 5.00	69.39 ± 6.23	**68.62 ± 6.54**	68.80 ± 3.91	**67.86 ± 5.67**	69.03 ± 4.93	68.23 ± 4.45	68.05 ± 5.11	<0.01
		PhotoInd	63.25 ± 3.78	**65.30 ± 4.84**	65.14 ± 3.91	65.95 ± 3.86	66.20 ± 4.30	**67.25 ± 4.26**	65.93 ± 4.59	**66.68 ± 4.30**	66.28 ± 3.98	64.92 ± 8.71	64.28 ± 5.31	
	Girls	AnthrInd	69.22 ± 4.60	67.73 ± 4.91	68.06 ± 3.79	69.43 ± 4.35	69.81 ± 5.07	69.32 ± 4.93	70.76 ± 4.27	69.73 ± 4.65	69.14 ± 4.14	66.16 ± 5.53	67.54 ± 4.18	<0.05
		PhotoInd	63.51 ± 3.92	62.92 ± 5.20	64.34 ± 4.12	65.73 ± 4.15	64.08 ± 4.05	63.26 ± 4.35	63.60 ± 4.40	63.79 ± 4.16	62.47 ± 4.41	61.32 ± 4.27	63.17 ± 4.48	
so-go/se-gn (bigonial width in relation to morphological facial height)	Boys	AnthrInd	95.78 ± 5.73	94.66 ± 6.09	93.30 ± 5.97	**93.74 ± 7.46**	89.92 ± 7.21	91.22 ± 6.21	92.89 ± 5.65	92.25 ± 5.84	91.82 ± 6.35	91.98 ± 6.76	92.40 ± 6.78	<0.01
		PhotoInd	100.17 ± 5.06	97.81 ± 6.09	97.32 ± 5.18	**95.18 ± 4.88**	95.01 ± 5.08	94.94 ± 6.10	95.82 ± 5.63	94.70 ± 6.39	95.29 ± 5.28	96.80 ± 5.70	98.44 ± 9.54	
	Girls	AnthrInd	93.92 ± 5.25	96.31 ± 6.04	95.52 ± 5.01	94.40 ± 5.46	94.34 ± 6.05	94.44 ± 6.67	92.59 ± 5.13	93.78 ± 5.68	93.78 ± 4.63	96.29 ± 6.63	93.13 ± 5.81	>0.05
		PhotoInd	100.00 ± 5.69	101.51 ± 6.62	99.02 ± 5.58	97.72 ± 5.00	99.83 ± 5.73	100.15 ± 5.70	98.86 ± 5.62	99.66 ± 5.71	104.37 ± 8.53	103.78 ± 6.47	100.73 ± 5.77	

In bold—no statistically significant difference between indices calculated from direct anthropometry and from photographs ($p \geq 0.05$), therefore, these methods.
AnthrInd—antropometrically determined indices.
PhotoInd—indices determined from photographs.
statistically significant difference between boys and girls' indices calculated from direct anthropometry measurements ($p < 0.05$).

Table 7. Comparison of indices containing eye parameters between values calculated from direct anthropometry and from photographs.

Index		10	11	12	13	14	15	16	17	18	19	20
en-en/pu-pu	Boys	X				X	X		X		X	X
	Girls	X			X	X	X	X	X		X	
en-en/ex-ex	Boys	X		X	X	X	X		X		X	
	Girls		X	X	X	X	X	X	X	X	X	
en-en/se-sto	Boys	X		X		X		X	X		X	X
	Girls	X	X	X	X	X	X	X	X		X	
en-en/se-gn	Boys	X	X	X		X	X		X		X	X
	Girls	X	X		X	X		X	X		X	X
pu-pu/ex-ex	Boys	X	X	X	X		X	X	X		X	X
	Girls										X	X
pu-pu/se-gn	Boys	X	X	X	X	X	X	X	X	X	X	X
	Girls	X	X	X	X	X	X	X	X	X	X	X
pu-pu/se-sto	Boys	X	X	X	X	X	X	X	X	X	X	X
	Girls	X	X		X	X				X	X	X
se-sto/ex-ex	Boys	X	X	X	X	X	X	X	X	X	X	X
	Girls		X	X	X	X	X	X	X		X	X

X—no statistically significant difference between indices calculated from direct anthropometry and from photographs ($p \geq 0.05$) (methods could be used interchangeably).

no statistically significant difference in boys between indices calculated from direct anthropometry and from photographs ($p \geq 0.05$) (methods could be used interchangeably).

no statistically significant difference in girls between indices calculated from direct anthropometry and from photographs ($p \geq 0.05$) (methods could be used interchangeably).

Table 8. Comparison of indices containing labial fissure width between values calculated from direct anthropometry and from photographs.

Index		10	11	12	13	14	15	16	17	18		19	20
en-en/ch-ch	boys	X					X		X		X		
	girls	X			X		X	X	X	X	X		X
ch-ch/pu-pu	boys	X	X	X	X	X	X	X	X	X	X		X
	girls	X	X	X	X	X	X	X	X	X	X		X
ch-ch/ex-ex	boys	X	X	X			X	X	X	X	X		X
	girls									X	X		X
ch-ch/go-go	boys		X	X	X	X	X	X	X				
	girls				X	X							
ch-ch/se-gn	boys	X	X	X	X		X	X	X	X	X	X	
	girls	X	X	X	X	X	X	X	X	X	X	X	
ch-ch/se-sto	boys	X	X	X	X	X	X	X	X	X	X	X	
	girls	X			X		X		X		X	X	

X—no statistically significant difference between indices calculated from direct anthropometry and from photographs ($p \geq 0.05$) (methods could be used interchangeably).

no statistically significant difference in boys between indices calculated from direct anthropometry and from photographs ($p \geq 0.05$) (methods could be used interchangeably).

no statistically significant difference in girls between indices calculated from direct anthropometry and from photographs ($p \geq 0.05$) (methods could be used interchangeably).

In most age groups, girls had relatively wider labial fissure in comparison with boys. A study analysing the facial indices of 12-year-olds revealed that boys had a larger upper lip height in relation to labial fissure width—this supports our finding that boys had longer faces relative to labial fissure width (Yeung et al. 2015).

Facial index (morphological facial height in relation to bizygomatic width) tended to be larger in boys than in girls. Another study researching the growth of Romanian children from 3.5 to 14.5 years of age also confirmed the increase in facial index (Ogodescu et al. 2021). However, a study analysing upper Himalayan indigenous tribal populations showed that even though morphological facial length and bizygomatic breadth were larger in males than in females, there was no significant difference in facial index between sexes (Dabhi et al. 2025). Values of facial indices were provided by a Latvian study analysing children from 1 to 15 years of age, however, girls and boys were attributed to one group (Grabcika et al. 2024). Another study investigated the faces of children from southern Mexico using cephalic and zygomandibular (bigonial width in relation to bizygomatic width) indices (Little et al. 2006). In comparison, our study findings showed zygomandibular index to be clearly smaller for both sexes. This demonstrates that the jaws of Lithuanian children are not as broad as those of Mexican children when compared to the distance between the cheekbones.

Our analysis revealed more indices showing stability in girls compared to boys. This finding is consistent with the results of another study—girls compared to boys tended to show smaller deviations from the predicted and the real facial morphology (Koudelová et al. 2019). Zygomandibular index showed a low variability in both sexes. Another study on 6-13-years-olds suggested that zygomandibular index decreased in boys and remained stable in girls (Little et al. 2006).

Other indices obtained in our study that were showing stability throughout the investigated time period, have not been researched elsewhere. Facial indices that exhibited the least variations could aid in facial identification. Indices that showed gradual changes could be useful in predicting how the face will develop during puberty.

Comparison of facial analysis using photographs with other facial investigation methods

In our current study we analysed if anthropometrically determined facial indices could be used interchangeably with the indices calculated from facial photographs from 10 to 20 years of age in both girls and boys. This is the first study investigating such a broad time period and comparing the methods of obtaining facial indices in both sexes.

However, there are some smaller scale studies comparing facial analysis using 2D facial photographs with direct anthropometry. It was found that bizygomatic and bigonial widths differed when measured by 2D and direct methods which is similar to the results of our study (Lim et al. 2022). Naif-de-Andrade et al. investigated orbital region, and their results showed no difference between direct anthropometry and computerised photogrammetry (Naif-de-Andrade et al. 2012). The investigation comparing direct anthropometry and the 2D method showed that 10 out of 14 measurements did not differ (Guyot et al. 2003). Our previous study analysed facial indices determined by three methods—direct anthropometry, professional photographs and non-professional photographs (Stukaite-Ruibiene et al. 2024). It was found that vertical facial parameters and eye dimensions may be used interchangeably between different methods in young adults.

Studies investigating 2D photoanthropometry show diverse results. It could be related to the limitations of 2D-photoanthropometry. They include parallax error, possible measurement errors due to landmark placement variability, and possible depth distortion (Brons et al. 2012; Lim et al. 2022). However, in our study all photographs were acquired under standardised conditions as mentioned in the methodology section, minimising these errors. As mentioned, the same digital camera and the distance to the camera were applied.

Comparison of the indices containing eye parameters determined by two methods

The indices containing eye parameters showed very high consistency between the two methods and this was similar in both sexes. One exception was biocular width in relation to interpupillary distance. Biocular width could be more complicated to measure than other eye parameters. One potential issue is that when measuring biocular width by a direct method, according to Farkas, the subject should be looking upwards (Farkas 1994), which is not the case when measuring from photographs.

Comparison of the indices containing nasal parameters and labial fissure width determined by two methods

The indices containing the nasal parameters calculated using direct anthropometry and from photographs largely differed. The indices containing nasal height may be used interchangeably more frequently than those specifying nasal width. Our previous study also indicated that nasal height was one of the measurements taken from photographs that reflected the true facial parameter (Stukaite-Ruibiene et al. 2024). Indices with nasal parameters for boys may be used more commonly than for girls. It is known that the nose and the nostrils of boys are larger and wider than those of girls (Holton et al. 2016). We noticed that the boys’ nostrils were not only wider, but also more sharply contoured in photos.

As for the labial fissure width, most of its indices obtained by the two methods showed high consistency. The corners of the labial (mouth) fissure are clearly visible in photographs without need for palpation to locate (Jayaratne and Zwahlen 2014). An exception could be labial fissure width in relation to bigonial width, as it was found to be quite reliable in boys but less reliable in girls, which was probably related to the sexual dimorphism of the jaw—it is more pronounced and better contoured in boys.

Comparison of the indices containing the main transverse facial parameters determined by two methods

All of the indices containing bizygomatic width showed significant differences among those calculated using direct anthropometry and photographs. We believe that the *zygion* point should not be used in future facial studies that use 2D images to analyse the dynamics of facial proportions. Other studies showed similar results—*zygion* was not accurately identified on photographs (Cummaudo et al. 2013) or it was very difficult to locate (Campomanes-Álvarez et al. 2015).

The indices containing bigonial width differed significantly between the two methods in girls. The *gonion* point was more accurately placed on male photographs, although the accuracy was also low. Mandibular parameters, especially the gonial angle, are known to be a significant predictor of sex (Arthanari et al. 2024). Our results suggest a difference in the mandibular shape between sexes. In addition, the *gonion* point is mostly detected by palpation (Farkas 1994), and when using photographs this is not an option.

Novelty and application of the study

Compared to other parts of the body, human faces vary greatly across the world (Sheehan and Nachman 2014). In particular, the midface region, including the nose, the eyes, the brow area and the cheekbones differ between populations (Guo et al. 2014). Therefore, it is important to study different populations to better determine the ranges of diversity and understand the dynamics of facial growth and proportions. Our study has provided the absolute values of facial indices from 10 to 20 years of age, and has been the first study to compare the indices obtained using direct anthropometry with the indices calculated using photographs. It is known that facial features vary greatly across populations (Gao et al. 2025). Therefore, this study could add to the literature describing the craniofacial features of Northern Europe and the Baltic region populations, especially for the dynamics of facial proportions during puberty.

The results could aid in improving aesthetical surgery methods and outcomes (Lisiecki and Gilman 2022; Maamari et al. 2022). Even though new technologies are emerging, photographs are regarded as one of the methods for future forensic studies (Flores et al. 2019; Dedouit et al. 2025). Our study showed that the dynamics of facial growth can be disclosed not only by direct anthropometry, but also by photographs. Our results could be useful for forensics, e.g. identifying missing persons, especially in cases of missing children when only photographs are available.

Conclusions

1. The dynamics of facial indices showed that eye proportions changed slightly from 10 to 20 years of age. However, in the context of other facial parameters, the eyes became smaller. The nose became wider at almost the same rate as the face grew vertically. The main transverse face parameters grew mostly evenly in relation to each other.
2. As for sexual differences, more indices remained stable during adolescence in girls than in boys. The faces of boys were significantly longer than those of girls in relation to interpupillary distance. Nose growth in boys showed more rapid changes than in girls. The lips were significantly relatively wider in most age groups in girls than in boys. The jaw was wider in boys than in girls in relation to all facial parameters.
3. Indices that were the most stable from 10 to 20 years of age included intercanthal width in relation to biocular width, nasal width in relation to morphological facial height, and bigonial width in relation to bizygomatic width. Facial heights relative to facial widths increased gradually, while eye parameters relative to facial heights decreased. The nasal index in boys fluctuated the most.

4. The indices that could be used interchangeably, calculated either from direct anthropometry or from photographs, most frequently included vertical parameters such as morphological facial height, nasal height, physiognomic upper facial height, and eye parameters such as interpupillary distance, intercanthal and biocular widths, and labial fissure width.

Author contributions

CRediT: **Egle Stukaite-Ruibiene**: Formal analysis, Investigation, Writing – original draft, Writing – review & editing; **Jonas Tutkus**: Investigation, Writing – review & editing; **Stefanie Ritz-Timme**: Conceptualization, Data curation, Funding acquisition, Investigation, Methodology, Resources, Supervision, Validation, Writing – review & editing; **Cristina Cattaneo**: Conceptualization, Data curation, Funding acquisition, Investigation, Methodology, Resources, Supervision, Validation, Writing – review & editing; **Zuzana Obertova**: Methodology, Supervision, Validation, Visualization, Writing – review & editing; **Renata Simkunaite-Rizgeliene**: Formal analysis, Investigation, Methodology, Resources, Writing – review & editing; **Arunas Barkus**: Data curation, Formal analysis, Investigation, Resources, Validation, Writing – review & editing; **Simona Gervickaite**: Data curation, Methodology, Software, Validation, Writing – review & editing; **Janina Tutkuviene**: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Resources, Supervision, Validation, Visualization, Writing – review & editing.

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Data availability statement

Data are available from the authors upon reasonable request.

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