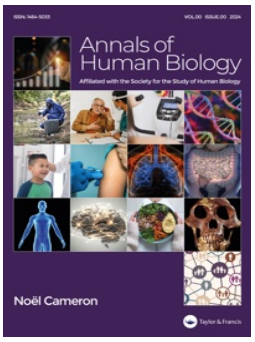

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RESEARCH PAPER

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Photoanthropometric study: are non-professional photographs suitable for objective and reliable analysis of facial features?

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ABSTRACT

Background: The face has been widely investigated using professionally taken frontal and lateral photographs, however, there is a lack of studies of non-professional facial photographs. It is not known if they could be suitable for facial analysis. The analysis of non-professional photographs could allow the performance of cost- effective longitudinal studies.

Aim: To determine if non-professional photographs could be used for a reliable analysis of facial features.

Subjects and methods: The frontal profiles of 18–21-year-olds (35 males, 39 females) were measured by direct anthropometry, in addition, professional photographs were taken and non-professional photographs were obtained. Anthropometric landmarks were superimposed on those photographs. The indices calculated on the basis of the measurements of direct anthropometry and both types of photographs were compared.

Results: The comparison of the measurements of direct anthropometry and professional photographs showed no difference between 14 out of 25 male and 10 out of 25 female facial indices ($p > 0.05$) after comparing the results of direct anthropometry with those of non-professional photographs, no difference was found in 8 out of 25 male and 7 out of 25 female indices. These indices were mostly composed of vertical parameters and eye measurements.

Conclusion: Vertical facial dimensions and eye measurements may not only be used interchangeably for both facial photographs and direct anthropometry, but may also be suitable for objective and reliable facial analyses.

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Anthropometry; facial indices; facial photographs; professional photographs; non-professional photographs

Introduction

Facial studies are beneficial for health care professionals in terms of planning treatment and assessing its outcomes in aesthetic surgery or orthodontics (Harrar et al. 2018; Vucic et al. 2019; Amezua et al. 2022). They are also useful for the evaluation of craniofacial anomalies (Cho et al. 2015; Tanaka et al. 2021). Research on human faces facilitates the identification of morphological facial features relevant for forensic facial identification (Yeung et al. 2015; Caplova et al. 2017; Weiliang et al. 2021; Nadeem et al. 2022). Most importantly, facial studies are beneficial for anthropologists and auxologists as such investigations provide knowledge of how faces change during certain times (Özkoçak & Özdemir, 2018; Lee et al. 2019; Patcas et al. 2022).

There is a broad spectrum of cross-sectional studies on the faces of adult populations related to facial ageing (Mydlová et al. 2015; Windhager et al. 2019; Velemínská et al. 2021). However, there is a lack of research on facial development in children and adolescents. Many studies of the faces of children are cross-sectional (Krimmel et al. 2015; Koudelová et al. 2019; Kumar et al. 2019). Data collection from the same individuals is time- consuming, therefore, there are only few longitudinal studies of children's faces (Wen et al. 2017; Launonen et al. 2023).

The analysis of two-dimensional (2D) images is a convenient, non-invasive, time-saving and low-cost approach, therefore, it is often used in facial studies (Moreton & Morley, 2011; Flores et al. 2019; Machado et al. 2019; Ayaz et al. 2020). The face has been widely investigated using professionally taken frontal and lateral photographs (Raschke et al. 2015; Packiriswamy et al. 2016; Cai et al. 2019). So far, studies on non-professional photographs are limited. There are studies on facial recognition, age estimation and facial attractiveness that have been carried out using non-professional photographs (Srisraluang & Rojnueangnit, 2021; Moradinejad et al. 2022). However, there is a lack of studies that could answer the question if it is possible to use non-professional photographs from personal archives for facial analysis. This can not only help to

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monitor the dynamics of facial growth and ageing, but can also save time in carrying out this type of longitudinal study.

The aim of this study was to clarify if non-professional photographs could be used for an objective and reliable analysis of facial features. For this purpose, the facial indicators obtained from direct anthropometry, professional and non-professional photographs were compared.

Subjects and methods

Study design

A study comparing three methods of facial measurements was carried out. Inclusion criteria were defined as follows: individuals of 18–21 years of age without facial anomalies, traumas or cosmetic facial surgeries. The study sample included the participants whose faces were measured by direct anthropometry, who were additionally professionally photographed and who provided non-professional photographs of their frontal faces. All the participants consented to the conditions of the study. Personal data were anonymised, an identification code was assigned to each participant. The investigation was part of the EC project ISEC (JLS/2007/ISEC/451) "Automated age estimation and identification of juvenile victims on pedopornographic contents". The study was approved by the Lithuanian Bioethics Committee (Approval No. 6B-09-264).

Study sample calculation

There were no analogous studies found to borrow means and standard deviations for effect size calculation to calculate the sample size. Therefore, a similar study comparing three groups of evaluation of facial attractiveness was followed as an example for the sample size (Moradinejad et al. 2022). The sample size in the mentioned study was 32 subjects divided into three groups. Thus, a similar sample size was selected for our study, that is 35 males and 39 females. This sample size has been estimated using UCSF Sample Size Calculators (University of California, San Francisco, USA) (Kohn 2024). The effect size for the two-group analytic study was calculated using the T statistic (with a non-centrality parameter): with the alpha of 0.05, $\beta = 0.2$, the present study (35 males and 39 females) demonstrated 80% power to detect an effect size of $E = 3.412$.

Direct anthropometry measurements

The facial measurements of 35 males and 39 females aged 18-21 years old were taken in millimetres using the standard methodology of direct anthropometry according to Farkas (Farkas, 1994). Martin-type instruments (GPM – *Siber Hegner*, Zurich) were used, including an anthropometer, a sliding calliper, and a small spreading calliper. The participants were seated with their head positioned in the Frankfort Horizontale. The measuring technique was standardised between three investigators. The results of this exercise were compared to avoid intra- and inter-observer differences. The intra- and inter-observer errors varied between ±1 mm for the measurements including landmarks demarcated by skeletal structures, such as *gnathion* or *subnasale* and ±3 mm for the measurements including landmarks that were difficult to palpate, such as *pupillare*. In total, ten craniofacial measurements were recorded. *Sellion* landmark (the most posterior point of the frontonasal contour in the midline of the base of the nasal root (Katina et al. 2016)) can be more precisely determined than *nasion*, therefore, *selion* was chosen instead of *nasion*.

Taking professional photographs

Frontal digital photographs were taken of the faces of the same young adults while seated, with a homogeneous light background applied to the photographs. The head of the participants was positioned in the Frankfort Horizontal plane (Santos et al. 2017). The facial expression was neutral, eyes opened (no eyewear), and hair did not cover the face and ears (including no beard or moustache).

The facial point *sellion* of each subject was chosen as the focus point. The landmark *sellion* was used since it has been identified in previous studies that *nasion* is difficult to target in the indirect craniofacial soft tissue investigation (Bahşi et al. 2021). The camera was positioned at 1.5 metres from the focus point.

Provision of non-professional photographs

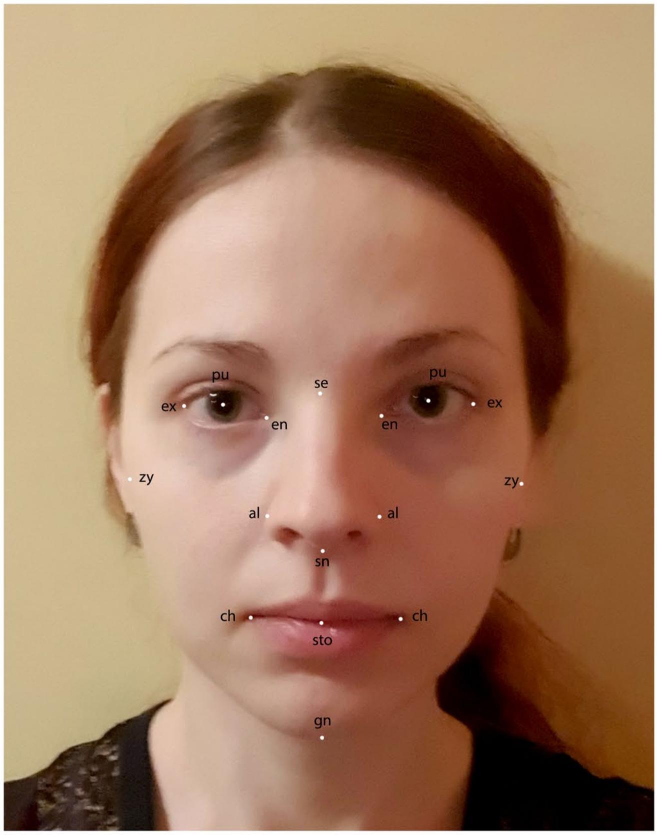
All the participants also provided non-professional photographs of their frontal faces, taken at the age range from 18 to 21 years, at the same age they were measured by direct anthropometry. The non-professional photographs, as the professional ones, included the photographs with a neutral facial expression, eyes opened (no eyewear), and hair not covering the face and ears.

Placing anthropometric landmarks on photographs

Anthropometric landmarks were manually placed on all the facial images using an open-source software *ImageJ* (Figure 1). Other studies have confirmed that the *frontotemporale* landmark is not accurately placed on photographs and is the most difficult landmark in terms of its reliability, and is also rarely visible on photographs (Cummaudo et al. 2013; Machado et al. 2019). Therefore, it was not selected as one of the facial parameters in our study.

Measuring facial parameters in photographs

The distances between the two landmarks of both professional and non-professional photographs were measured in pixels. The measurements in pixel, a non-dimensional parameter, allowed a comparison of facial indices between both types of photographs considering the fact that the quality and the distance from the camera to the subject varied for non-professional photographs. In total, ten facial parameters were measured (Table 1).



Facial landmark abbreviation	Landmark definition
zy	*zygion*
se	*sellion*
sn	*subnasale*
sto	*stomion*
gn	*gnathion*
en	*endocanthion*
ex	*exocanthion*
pu	*pupillare*
al	*alare*
ch	*cheilion*

Figure 1. Localisation of anthropometric landmarks on non-professional photograph (personal photograph of the author, 21 years of age).

Firstly, a pilot study was performed to check the reliability of the measurements of the photographs. Ten professional photographs were measured three times by the main investigator during 24-hour intervals. The intra-observer agreement was calculated using the intraclass correlation coefficient. It was found as excellent – 0.999. Then the same ten photographs were additionally measured by two other investigators. The inter-observer agreement was excellent – 0.994. All the investigators were experienced in facial metric research. After this exercise, all the photographs (professional and non-professional) were measured by the main investigator.

Table 1. Descriptions of craniofacial measurements with landmark definitions obtained in this study.

Measurement (landmark abbreviations)	Measurement description
1. Face width (zy-zy)	Maximal distance between the most lateral points of the cheekbones
2. Morphological face height (se-gn)	Distance between the most posterior point of the frontonasal soft tissue contour in the midline of the base of the nasal root the most anterior-inferior mid-point of the chin
3. Interpupillary distance (pu-pu)	Distance between the centre of the right and left pupils with eyes focused straight ahead
4. Intercanthal width (en-en)	Distance between the points at the most medial corners (intersection of upper and lower eyelid) of the right and left eye fissure
5. Biocular width (ex-ex)	Distance between the points at the most lateral corners (intersection of upper and lower eyelid) of the right and left eye fissure
6. Nose width (al-al)	Distance the most lateral points on the right and left wing of a nose
7. Labial width (ch-ch)	Distance between the right and left corners of the labial commissure
8. Physiognomic upper facial height (se-sto)	Distance between the most posterior point of the frontonasal soft tissue contour in the midline of the base of the nasal root and the midpoint of the labial fissure with mouth closed
9. Nose height (se-sn)	Distance between the most posterior point of the frontonasal soft tissue contour in the midline of the base of the nasal root and the point at the midline of the nasal base where the nasal septum and the skin surface of the upper lip meet
10. Lower face height (sn-gn)	Distance between the point at the midline of the nasal base where the nasal septum and the skin surface of the upper lip meet and the most anterior-inferior mid-point of the chin

Table 2. List of facial indices calculated.

Indices containing intercanthal width	Indices containing biocular width	Indices containing interpupillary distance	Other indices
en-en/al-al	al-al/ex-ex	al-al/pu-pu	al-al/ch-ch
en-en/ch-ch	ch-ch/ex-ex	ch-ch/pu-pu	al-al/se-gn
en-en/ex-ex	pu-pu/ex-ex	pu-pu/se-gn	al-al/se-sn
en-en/pu-pu	se-sto/ex-ex	pu-pu/zy-zy	al-al/se-sto
en-en/se-gn		pu-pu/se-sto	ch-ch/se-sto
en-en/zy-zy			ch-ch/se-gn
en-en/se-sn			se-gn/zy-zy
en-en/se-sto			se-sto/zy-zy

Calculation of facial indices

The relationship between two facial parameters was evaluated by calculating facial indices. The measurements taken by direct anthropometry were recorded in millimetres and the measurements from photographs were taken in pixels, therefore, facial indices were a convenient method to compare all three types of measurements.

The indices were calculated by dividing one facial dimension (usually a smaller one) by another facial dimension (usually larger, or vertical if the numerator was horizontal) and multiplied by 100. In total, 25 facial indices were calculated (Table 2).

Statistical analysis

The distribution of the data was checked using the Shapiro-Wilk test of normality. It revealed that the data were not normally distributed, therefore, the non-parametric Mann-Whitney

U test was applied to compare the medians between different types of measurements (direct anthropometry vs professional photographs, direct anthropometry vs non-professional photographs, and professional photographs vs non-professional photographs) for males and females separately. The interquartile range (IQR) was reported. All statistical tests were performed with the SPSS® 21.0 software package (IBM®, New York, USA). The level of statistical significance was set at 5% ($p < 0.05$).

Results

The indices derived from direct anthropometry, professional photographs and non-professional photographs were compared.

Comparison of indices derived from direct anthropometry and professional photographs

The indices that did not differ statistically between professional photographs and direct anthropometry ($p > 0.05$), and were the same for males and females included pu-pu/se-gn, se-sto/ex-ex, en-en/pu-pu, en-en/se-sn, ch-ch/se-gn, en-en/se-sto, en-en/se-gn, pu-pu/se-sto (Table 3). Moreover, in males only six indices (ch-ch/pu-pu, ch-ch/ex-ex, ch-ch/se-sto, en-en/al-al, en-en/ch-ch, al-al/se-sn) did not differ ($p > 0.05$) while in females only two (en-en/ex-ex, al-al/se-gn).

Thus, the indices of direct anthropometry and professional photographs that did not differ statistically mostly contained vertical parameters and eye measurements. None of these indices contained bizygomatic width.

Comparison of indices derived from direct anthropometry and non-professional photographs

There were five indices that did not differ both in males and females ($p > 0.05$) (pu-pu/se-gn, se-sto/ex-ex, ch-ch/se-gn, en-en/ch-ch, ch-ch/pu-pu) (Table 4). In addition, no significant difference was found between three indices only in males such as ch-ch/se-sto, en-en/al-al, al-al/ch-ch ($p > 0.05$). Two indices did not differ only in females –en-en/se-sn and al-al/se-gn.

Most indices that did not differ when comparing direct anthropometry to non-professional photographs included vertical parameters and eye measurements, none of the indices included bizygomatic width.

Comparison of indices derived from professional and non-professional photographs

In total, seven of 25 (28%) indices did not differ ($p > 0.05$) both in male and female professional and non-professional photographs (pu-pu/se-gn, al-al/pu-pu, al-al/ex-ex, se-sto/zy-zy, en-en/ch-ch, pu-pu/se-sto, pu-pu/ex-ex) (Table 5). In addition to the indices which were the same in males and females, one index (en-en/al-al) did not differ only in females ($p > 0.05$) and 9 (ch-ch/pu-pu, al-al/se-sto, al-al/ch-ch, al-al/se-gn, se-sto/ex-ex, se-gn/zy-zy, al-al/se-sn, pu-pu/zy-zy, ch-ch/se-gn) only in males.

No clear tendency was seen after matching the indices between professional and non-professional photographs containing all possible measurements.

Table 3. Comparison of medians of facial indices in females and males between those calculated from direct anthropometry and from professional photographs.

	Males			Females		
Index	Professional photographs median (IQR)	Direct anthropometry median (IQR)	Mann Whitney U Test p-value	Professional photographs median (IQR)	Direct anthropometry median (IQR)	Mann Whitney U Test p-value
al-al/ch-ch	76 (72-80)	72 (68-76)	<0.01	76 (75-79)	68 (63-71)	<0.001
al-al/ex-ex	42 (41-44)	39 (37-41)	<0.001	40 (39-42)	36 (35-39)	<0.001
al-al/pu-pu	59 (57-63)	56 (53-59)	<0.01	58 (55-61)	53 (50-57)	<0.001
al-al/se-gn	32 (30-34)	30 (28-32)	<0.01	32 (31-33)	29 (28-31)	**0.08**
al-al/se-sn	70 (67-74)	69 (64-73)	**0.35**[*]	71 (68-73)	67 (64-71)	<0.01
al-al/se-sto	50 (47-51)	47 (44-50)	0.02	50 (48-52)	46 (44-49)	<0.001
ch-ch/ex-ex	56 (52-59)	55 (52-58)	**0.28**	53 (51-55)	55 (53-58)	0.02
ch-ch-/pu-pu	79 (74-83)	79 (76-82)	**0.86**	76 (72-79)	79 (75-84)	<0.01
ch-ch/se-gn	42 (39-44)	42 (39-44)	**0.68**	42 (40-44)	43 (41-46)	**0.08**
ch-ch/se-sto	65 (62-71)	67 (62-70)	**0.85**	65 (63-69)	67 (65-73)	0.03
en-en/al-al	86 (82-91)	88 (84-96)	**0.06**	90 (84-95)	100 (89-102)	<0.001
en-en/ch-ch	65 (61-69)	65 (61-67)	**0.56**	67 (64-72)	65 (61-69)	0.02
en-en/ex-ex	36 (35-37)	35 (34-37)	0.04	36 (35-36)	35 (34-36)	**0.22**
en-en/pu-pu	51 (49-53)	50 (49-53)	**0.66**	51 (50-52)	51 (49-53)	**0.65**
en-en/se-gn	27 (27-28)	27 (25-28)	**0.25**	29 (27-30)	28 (26-29)	**0.25**
en-en/se-sn	60 (56-65)	60 (57-67)	**0.45**	63 (60-67)	65 (61-68)	**0.2**
en-en/se-sto	43 (41-46)	42 (41-44)	**0.73**	45 (43-47)	44 (43-47)	**0.63**
en-en/zy-zy	27 (25-28)	22 (21-23)	<0.001	26 (25-28)	22 (21-23)	<0.001
pu-pu/ex-ex	71 (70-72)	69 (68-70)	<0.001	70 (69-71)	69 (68-70)	0.04
pu-pu/se-gn	53 (52-54)	53 (51-55)	**0.32**	56 (54-58)	55 (53-58)	**0.34**
pu-pu/se-sto	83 (80-87)	83 (81-86)	**0.93**	88 (83-91)	87 (83-90)	**0.75**
pu-pu/zy-zy	53 (50-54)	43 (41-44)	<0.001	51 (50-52)	43 (42-44)	<0.001
se-gn/zy-zy	98 (94-102)	82 (77-85)	<0.001	93 (89-96)	79 (76-82)	<0.001
se-sto/ex-ex	86 (81-88)	83 (79-86)	**0.12**	80 (77-83)	80 (77-82)	**0.54**
se-sto/zy-zy	62 (59-66)	51 (49-54)	<0.001	59 (57-61)	50 (48-52)	<0.001

[*]Bold – statistically significant values (indices which did not differ).

Table 4. Comparison of medians of facial indices in females and males between those calculated from direct anthropometry and from non-professional photographs.

	Males			Females		
Index	Non-professional photographs median (IQR)	Direct anthropometry median (IQR)	Mann Whitney U Test p-value	Non-professional photographs median (IQR)	Direct anthropometry median (IQR)	Mann Whitney U Test p-value
al-al/ch-ch	74 (71-78)	72 (68-76)	**0.08**[*]	74 (70-76)	68 (63-71)	<0.001
al-al/ex-ex	42 (41-45)	39 (37-41)	<0.001	41 (39-45)	36 (35-39)	<0.001
al-al/pu-pu	61 (57-64)	56 (53-59)	<0.01	59 (55-62)	53 (50-57)	<0.001
al-al/se-gn	32 (30-33)	30 (28-32)	<0.01	33 (31-34)	29 (28-31)	**0.18**
al-al/se-sn	72 (69-79)	69 (64-73)	0.03	73 (69-78)	67 (64-71)	<0.001
al-al/se-sto	50 (48-54)	47 (44-50)	<0.01	53 (50-55)	46 (44-49)	<0.001
ch-ch/ex-ex	58 (54-61)	55 (52-58)	<0.01	57 (53-60)	55 (53-58)	0.05
ch-ch-/pu-pu	82 (76-86)	79 (76-82)	**0.11**	81 (76-86)	79 (75-84)	**0.25**
ch-ch/se-gn	43 (41-45)	42 (39-44)	**0.07**	44 (43-46)	43 (41-46)	**0.18**
ch-ch/se-sto	69 (63-74)	67 (62-70)	**0.07**	72 (69-76)	67 (65-73)	0.02
en-en/al-al	89 (85-94)	88 (84-96)	**0.53**	92 (87-97)	100 (89-102)	0.01
en-en/ch-ch	66 (63-72)	65 (61-67)	**0.08**	67 (61-71)	65 (61-69)	**0.29**
en-en/ex-ex	39 (37-40)	35 (34-37)	<0.001	37 (35-39)	35 (34-36)	<0.001
en-en/pu-pu	54 (52-56)	50 (49-53)	<0.001	54 (52-56)	51 (49-53)	<0.001
en-en/se-gn	29 (28-30)	27 (25-28)	<0.001	30 (28-32)	28 (26-29)	<0.01
en-en/se-sn	65 (61-70)	60 (57-67)	<0.01	66 (62-71)	65 (61-68)	**0.22**
en-en/se-sto	46 (44-48)	42 (41-44)	<0.001	48 (45-52)	44 (43-47)	<0.001
en-en/zy-zy	29 (28-30)	22 (21-23)	<0.001	28 (27-31)	22 (21-23)	<0.001
pu-pu/ex-ex	71 (70-72)	69 (68-70)	<0.001	70 (69-71)	69 (68-70)	0.03
pu-pu/se-gn	53 (52-54)	53 (51-55)	**0.31**	56 (53-58)	55 (53-58)	**0.49**
pu-pu/se-sto	86 (82-88)	83 (81-86)	0.05	90 (85-93)	87 (83-90)	0.03
pu-pu/zy-zy	53 (51-55)	43 (41-44)	<0.001	53 (51-55)	43 (42-44)	<0.001
se-gn/zy-zy	101 (96-106)	82 (77-85)	<0.001	96 (92-102)	79 (76-82)	<0.001
se-sto/ex-ex	83 (80-87)	83 (79-86)	**0.72**	77 (76-82)	80 (77-82)	**0.27**
se-sto/zy-zy	63 (59-65)	51 (49-54)	<0.001	60 (57-62)	50 (48-52)	<0.001

[*]Bold – statistically significant values (indices which did not differ).

Table 5. Comparison of medians of facial indices in females and males between those calculated from professional and non-professional photographs.

	Males			Females		
Index	Non-professional photographs median (IQR)	Professional photographs median (IQR)	Mann Whitney U Test p-value	Non-professional photographs median (IQR)	Professional photographs median (IQR)	Mann Whitney U Test p-value
al-al/ch-ch	74 (71-78)	76 (72-80)	**0.28**[*]	74 (70-76)	76 (75-79)	<0.01
al-al/ex-ex	42 (41-45)	42 (41-44)	**0.45**	41 (39-45)	40 (39-42)	**0.11**
al-al/pu-pu	61 (57-64)	59 (57-63)	**0.63**	59 (55-62)	58 (55-61)	**0.22**
al-al/se-gn	32 (30-33)	32 (30-34)	**0.83**	33 (31-34)	32 (31-33)	<0.001
al-al/se-sn	72 (69-79)	70 (67-74)	**0.11**	73 (69-78)	71 (68-73)	0.04
al-al/se-sto	50 (48-54)	50 (47-51)	**0.27**	53 (50-55)	50 (48-52)	<0.01
ch-ch/ex-ex	58 (54-61)	56 (52-59)	0.03	57 (53-60)	53 (51-55)	<0.001
ch-ch-/pu-pu	82 (76-86)	79 (74-83)	**0.08**	81 (76-86)	76 (72-79)	<0.001
ch-ch/se-gn	43 (41-45)	42 (39-44)	**0.1**	44 (43-46)	42 (40-44)	<0.001
ch-ch/se-sto	69 (63-74)	65 (62-71)	0.03	72 (69-76)	65 (63-69)	<0.001
en-en/al-al	89 (85-94)	86 (82-91)	**0.02**	92 (87-97)	90 (84-95)	**0.25**
en-en/ch-ch	66 (63-72)	65 (61-69)	**0.15**	67 (61-71)	67 (64-72)	**0.3**
en-en/ex-ex	39 (37-40)	36 (35-37)	<0.001	37 (35-39)	36 (35-36)	<0.01
en-en/pu-pu	54 (52-56)	51 (49-53)	<0.001	54 (52-56)	51 (50-52)	<0.001
en-en/se-gn	29 (28-30)	27 (27-28)	<0.001	30 (28-32)	29 (27-30)	0.04
en-en/se-sn	65 (61-70)	60 (56-65)	<0.01	66 (62-71)	63 (60-67)	<0.01
en-en/se-sto	46 (44-48)	43 (41-46)	<0.001	48 (45-52)	45 (43-47)	<0.001
en-en/zy-zy	29 (28-30)	27 (25-28)	<0.001	28 (27-31)	26 (25-28)	<0.001
pu-pu/ex-ex	71 (70-72)	71 (70-72)	**0.21**	70 (69-71)	70 (69-71)	**0.68**
pu-pu/se-gn	53 (52-54)	53 (52-54)	**0.87**	56 (53-58)	56 (54-58)	**0.96**
pu-pu/se-sto	86 (82-88)	83 (80-87)	**0.06**	90 (85-93)	88 (83-91)	**0.06**
pu-pu/zy-zy	53 (51-55)	53 (50-54)	**0.13**	53 (51-55)	51 (50-52)	<0.01
se-gn/zy-zy	101 (96-106)	98 (94-102)	**0.06**	96 (92-102)	93 (89-96)	0.01
se-sto/ex-ex	83 (80-87)	86 (81-88)	**0.21**	77 (76-82)	80 (77-83)	0.05
se-sto/zy-zy	63 (59-65)	62 (59-66)	**0.61**	60 (57-62)	59 (57-61)	**0.5**

[*]Bold – statistically significant values (indices which did not differ).

Discussion

So far, there have been many cross-sectional facial studies, facial beauty studies or studies that investigate age estimation from faces and face recognition (Machado et al. 2019; Velemínská et al. 2021; Nadeem et al. 2022; Jung et al. 2024). However, to our knowledge, this is the first study that compares the parameters obtained from direct anthropometry to those measured on photographs in an attempt to determine if non-professional photographs are suitable for a reliable facial analysis.

Our study showed that there was no difference in more than half of the facial 18-21 year-old male and almost half of the female indices calculated by direct anthropometry and those obtained by measuring professional photographs,. An overall difference is expected between the indices derived from direct measurements and the indices derived from photographs, particularly the indices derived from measurements that require the palpation of landmarks, as one limitation of image analysis is the inability to directly assess soft tissue (Moreton & Morley, 2011).

Most indices (94.1%) that did not differ between direct anthropometry and non-professional photographs included vertical parameters and eye measurements such as the distance between the points at the most medial and lateral corners of the eyes and between pupils; the distance between the base of the nasal root and the mid-point of the chin; the distance between the base of the nasal root and the midpoint of the labial fissure; the distance between the point of the nasal base and the mid-point of the chin.

Thus, it could be stated that vertical facial dimensions (morphological facial height, physiognomic upper facial height, nasal height) and eye measurements (intercanthal width, interpupillary distance, biocular width) may be used interchangeably between direct anthropometry and professional and non-professional photographs and may be suitable for facial analysis using non-professional photographs.

The results of our study showed that of the indices showing no differences between those obtained on the basis of direct anthropometry and two types of photographs, none contained bizygomatic width. Also, our pilot study that had been carried out before measuring all the photographs revealed that the measurements of bizygomatic width taken by three investigators differed the most. This can be explained by the lack of a precise location of *zygion* landmark on the photographs. According to the study conducted by Campomanes-Álvarez et al. 39 operators located facial landmarks on photographs, the frequency of landmark location was studied together with their dispersion (Campomanes-Álvarez et al. 2015). It was found that *zygion* was one of the most difficult landmarks to locate. Another study also investigated inter- and intra-observer dispersions related to the facial landmark identification on photographs and suggested that *zygion* landmark is not accurately placed on photographs (Cummaudo et al. 2013) which is consistent with the results of our study.

Our study showed that more facial indices that did not differ were found in males, compared to females. Additionally, less of the female indices contained labial width (distance between the right and left corners of the labial commissure) in contrast to males – one-third in females vs two-thirds in males. More errors occurring when registering indicators for women than for men may be due to the sexual dimorphism of facial appearance. Males are known to have more angular faces than females (Mydlová et al. 2015). This may have allowed for more accurate placement of landmarks in the male photos. Similarly to the findings of our study, another study found that 50% of male facial indices on X-rays and photographs did not differ, compared to 33.3% of women (Budai et al. 2003).

In addition, our study compared the indices derived from professional photographs versus non-professional photographs. Matching indices varied, no clear tendency was seen. The indices included many parameters that were different after they had been measured by direct anthropometry and both types of photographs e.g. bizygomatic width, also more times included labial width and nose width. Therefore, we found out the parameters that could be used interchangeably between different types of photographs but not between direct anthropometry and photographs. These results could be beneficial in forensic science such as in cases of missing children when only non-professional photographs are available. However, we have not found any studies on the validity of professional versus non-professional photographs, with which our results could be compared.

To our knowledge only two studies analysed facial parameters obtained from direct anthropometry in comparison to professional photographs of the same individuals (Guyot et al. 2003; Cascos et al. 2023). One study revealed that 10 out of 14 indices did not differ between the two methods (Guyot et al. 2003). Of these, most of the indices included vertical measurements (upper face height, lower face height, mandibular height, and upper lip height), which are analogous to our study and suggest that these parameters may be suitable for face analysis using photographs. However, these measurements were of the lateral face. In other studies, photographs were compared not only by means of direct measurements, but also with results obtained from a 3D scanner (Cascos et al. 2023). The 2D method using photography was found to be inaccurate for facial soft tissue reconstruction, contrary to our study.

There are also studies comparing cephalometric measurements with direct anthropometry or photography (Budai et al. 2003; Zhang et al. 2007). One study compared measurements obtained by direct anthropometry on the lateral faces of women and men with cephalometric (taken from X-ray) measurements (Budai et al. 2003). Vertical measurements obtained by both methods were found to be similar when compared to their normative data in healthy populations, suggesting similarity to the results of our study.

Another study also compared facial measurements from X-rays with photometric ones, and found that linear measurements were reliably measured from facial photographs (Zhang et al. 2007). Vertical measurements obtained by both methods were found to be similar when compared to their normative data in healthy populations, suggesting similarity to the results of our study. Nevertheless, the aforementioned studies only assessed lateral faces, and horizontal face measurements, such as eye measurements, which were reliable in our study, were not investigated.

Our study included only the 18-21 age group. Two other cross-sectional studies comparing facial measurements from direct anthropometry and professional photographs included a population older than 18 years (Cascos et al. 2023) and 14 participants between the ages of 5 and 38 years (Guyot et al. 2003). A comparative study of the three measurement methods in other age groups would be useful, e.g. for adults and the elderly, to find out whether the appropriate indicators for facial analysis from non-professional photos would be the same as for the 18-21-year-old group.

This study provides unique results, as to our knowledge no studies have so far compared measurements taken on a living person to those taken on professional and non-professional photographs. As mentioned above, the results of our study may be particularly important for anthropological longitudinal studies of long-term facial dynamics, such as growth and ageing, when only non-professional photographs are available. Longitudinal studies are usually time-consuming, but the use of non-professional photographs can reduce time costs. The results are also important for forensics, where uncontrolled images are part of case work. Additional practical applications of the results may include collaboration with computer scientists to improve automated facial recognition systems.

Conclusions

Facial indices which consisted mainly of vertical facial dimensions (morphological face height, physiognomic upper facial height, nose height and lower face height) and eye measurements (intercanthal width, biocular width, interpupillary distance) did not differ between direct anthropometry and professional and non-professional photographs. This shows that non-professional photographs of young individuals can be used for face analysis based on these parameters. They can be used interchangeably between facial anthropometry and both types of photographs, providing a relatively objective analysis of the facial peculiarities using non-professional photographs to investigate age-related dynamics in young people and may be particularly suitable for longitudinal facial studies.

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Data availability statement

Data are available from the authors upon reasonable request.

References

Amezua X, Iturrate M, Garikano X, Solaberrieta E. 2022. Analysis of the influence of the facial scanning method on the transfer accuracy of a maxillary digital scan to a 3D face scan for a virtual facebow technique: an in vitro study. J Prosthet Dent. 128(5):1024–1031. doi: 10.1016/j.prosdent.2021.02.007.

Ayaz I, Shaheen E, Aly M, Shujaat S, Gallo G, Coucke W, Politis C, Jacobs R. 2020. Accuracy and reliability of 2-dimensional photography versus 3-dimensional soft tissue imaging. Imaging Sci Dent. 50(1):15–22. doi: 10.5624/isd.2020.50.1.15.

Bahşi I, Orhan M, Kervancioğlu P. 2021. The confusion of determining the landmark in the craniofacial soft tissue analyzes: nasion or sellion? J Craniofac Surg. 32(6):e602–e603. doi: 10.1097/SCS.0000000000007900.

Budai M, Farkas LG, Tompson B, Katic M, Forrest CR. 2003. Relation between anthropometric and cephalometric measurements and proportions of the face of healthy young white adult men and women. J Craniofacial Surgery. 14(2):154–161. discussion 162-163. doi: 10.1097/00001665-200303000-00004.

Cai X, Chen Y, Li Q, Ma H, Tang Z, Nie C, Lu R. 2019. Anthropometric analysis on the ocular region morphology of children and young adults in Chinese Han population. Ophthalmic Plast Reconstr Surg. 35(4):326–332. doi: 10.1097/IOP.0000000000001245.

Campomanes-Álvarez BR, Ibáñez O, Navarro F, Alemán I, Cordón O, Damas S. 2015. Dispersion assessment in the location of facial landmarks on photographs. Int J Legal Med. 129(1):227–236. doi: 10.1007/s00414-014-1002-4.

Caplova Z, Compassi V, Giancola S, Gibelli DM, Obertová Z, Poppa P, Sala R, Sforza C, Cattaneo C. 2017. Recognition of children on age-different images: facial morphology and age-stable features. Sci Justice. 57(4):250–256. doi: 10.1016/j.scijus.2017.03.005.

Cascos R, Ortiz del Amo L, Álvarez-Guzmán F, Antonaya-Martín JL, Celemín-Viñuela A, Gómez-Costa D, Zafra-Vallejo M, Agustín-Panadero R, Gómez-Polo M. 2023. Accuracy between 2D photography and dual-structured light 3D facial scanner for facial anthropometry: a clinical study. Journal of Clinical Medicine. 12(9):3090. doi: 10.3390/jcm12093090.

Cho D, Choi D-S, Jang I, Cha B-K. 2015. Changes in natural head position after orthognathic surgery in skeletal Class III patients. Am J Orthod Dentofacial Orthop. 147(6):747–754. doi: 10.1016/j.ajodo.2015.01.026.

Cummaudo M, Guerzoni M, Marasciuolo L, Gibelli D, Cigada A, Obertovà Z, Ratnayake M, Poppa P, Gabriel P, Ritz-Timme S, et al. 2013. Pitfalls at the root of facial assessment on photographs: a quantitative study of accuracy in positioning facial landmarks. Int J Legal Med. 127(3):699–706. doi: 10.1007/s00414-013-0850-7.

Farkas LG. 1994. Anthropometry of the head and face. New York: Raven Press.

Flores MRP, Machado CEP, Gallidabino MD, de Arruda GHM, da Silva RHA, de Vidal FB, Melani RFH. 2019. Comparative assessment of a novel photo-anthropometric landmark-positioning approach for the analysis of facial structures on two-dimensional images. J Forensic Sci. 64(3):828–838. doi: 10.1111/1556-4029.13935.

Guyot L, Dubuc M, Richard O, Philip N, Dutour O. 2003. Comparison between direct clinical and digital photogrammetric measurements in patients with 22q11 microdeletion. Int J Oral Maxillofac Surg. 32(3):246–252. doi: 10.1054/ijom.2002.0379.

Harrar H, Myers S, Ghanem AM. 2018. Art or science? An evidence-based approach to human facial beauty a quantitative analysis towards an informed clinical aesthetic practice. Aesthetic Plast Surg. 42(1):137–146. doi: 10.1007/s00266-017-1032-7.

Jung SG, Wu X, Hwang K, Han S-H. 2024. Anthropometric analysis of the faces of Chinese beauty pageant winners, from the early 20th century to the present. J Craniofacial Surg. 35(3):978–983. doi: 10.1097/SCS.0000000000010026.

Katina S, McNeil K, Ayoub A, Guilfoyle B, Khambay B, Siebert P, Sukno F, Rojas M, Vittert L, Waddington J, et al. 2016. The definitions of three-dimensional landmarks on the human face: an interdisciplinary view. J Anat. 228(3):355–365. doi: 10.1111/joa.12407.

Kohn MJS. 2024. *Means – effect size | sample size calculators*. Accessed April 6, 2024. https://sample-size.net/means-effect-size/.

Koudelová J, Hoffmannová E, Dupej J, Velemínská J. 2019. Simulation of facial growth based on longitudinal data: age progression and age regression between 7 and 17 years of age using 3D surface data. PLoS One. 14(2):e0212618. doi: 10.1371/journal.pone.0212618.

Krimmel M, Breidt M, Bacher M, Müller-Hagedorn S, Dietz K, Bülthoff H, Reinert S, Kluba S. 2015. Three-dimensional normal facial growth from birth to the age of 7 years. Plast Reconstr Surg. 136(4):490e–501e. doi: 10.1097/PRS.0000000000001612.

Kumar A, Tandon P, Singh GK, Singh GP. 2019. Soft tissue growth changes from 8 to 16 years of age: a cross-sectional study. Natl J Maxillofac Surg. 10(2):161–167. doi: 10.4103/njms.NJMS_18_16.

Launonen AM, Vuollo V, Aarnivala H, Heikkinen T, Pirttiniemi P, Valkama AM, Harila V. 2023. A longitudinal study of facial asymmetry in a normal birth cohort up to 6 years of age and the predisposing factors. Eur J Orthodontics. 45(4):396–407. doi: 10.1093/ejo/cjad012.

Lee H-Y, Cha S, Ban H-J, Kim I-Y, Park B-R, Kim I-J, Hong K-W. 2019. The age distribution of facial metrics in two large Korean populations. Sci Rep. 9(1):14564. doi: 10.1038/s41598-019-51121-z.

Machado CEP, Santiago BM, Lima LNC, Gonzales PS, Franco A, Vidal FdB, Aguilera IA, Guimarães MA. 2019. Applicability of a pre-established set of facial proportions from frontal photographs in forensic age estimation of a Brazilian population. Forensic Sci Int. 301:e1–e7. doi: 10.1016/j.forsciint.2019.05.009.

Moradinejad M, Rekabi A, Ashtiani AH, Atashkar N, Rakhshan V. 2022. Psychometric and perceptometric comparisons of the perspectives of orthodontists, oral and maxillofacial surgeons, and laypeople of different ages and sexes towards beauty of female jaw angles (intergonial widths and gonial heights) on frontal and three-quarter views. Biomed Res Int. 2022:2595662. doi: 10.1155/2022/2595662.

Moreton R, Morley J. 2011. Investigation into the use of photoanthropometry in facial image comparison. Forensic Sci Int. 212(1–3):231–237. doi: 10.1016/j.forsciint.2011.06.023.

Mydlová M, Dupej J, Koudelová J, Velemínská J. 2015. Sexual dimorphism of facial appearance in ageing human adults: a cross-sectional study. Forensic Sci Int. 257:519.e1–519.e9. doi: 10.1016/j.forsciint.2015.09.008.

Nadeem A, Ashraf M, Rizwan K, Qadeer N, AlZahrani A, Mehmood A, Abbasi QH. 2022. A Novel integration of face-recognition algorithms with a soft voting scheme for efficiently tracking missing person in challenging large-gathering scenarios. Sensors (Basel, Switzerland). 22(3):1153. doi: 10.3390/s22031153.

Özkoçak V, Özdemir F. 2018. Age-related changes in the external noses of the anatolian men. Aesthetic Plast Surg. 42(5):1336–1342. doi: 10.1007/s00266-018-1170-6.

Packiriswamy V, Bashour M, Nayak S. 2016. Anthropometric analysis of the South Indian woman's nose. Facial Plast Surg. 32(3):304–308. doi: 10.1055/s-0036-1581140.

Patcas R, Keller H, Markic G, Beit P, Eliades T, Cole TJ. 2022. Craniofacial growth and SITAR growth curve analysis. Eur J Orthod. 44(3):325–331. doi: 10.1093/ejo/cjab059.

Raschke GF, Rieger UM, Peisker A, Djedovic G, Gomez-Dammeier M, Guentsch A, Schaefer O, Schultze-Mosgau S. 2015. Morphologic outcome of bimaxillary surgery—An anthropometric appraisal. Med Oral Patol Oral Cir Bucal. 20(1):e103–e110. doi: 10.4317/medoral.19978.

Santos RMGd, De Martino JM, Haiter Neto F, Passeri LA. 2017. Influence of different setups of the Frankfort horizontal plane on 3-dimensional cephalometric measurements. Am J Orthodontics and Dentofacial Orthopedics. 152(2):242–249. doi: 10.1016/j.ajodo.2016.12.023.

Srisraluang W, Rojnueangnit K. 2021. Facial recognition accuracy in photographs of Thai neonates with Down syndrome among physicians and the Face2Gene application. Am J Med Genet A. 185(12):3701–3705. doi: 10.1002/ajmg.a.62432.

Tanaka S, Fujimoto Y, Otsuki K, Kogo M. 2021. Validity of the combined use of two esthetic rating systems, the infant index and 5-point aesthetic index, for pre- and postsurgical evaluation of cleft lip repair. J Cranio-Maxillo-Facial Surg. 49(4):304–311. doi: 10.1016/j.jcms.2020.09.009.

Velemínská J, Fleischmannová N, Suchá B, Dupej J, Bejdová Š, Kotěrová A, Brůžek J. 2021. Age-related differences in cranial sexual dimorphism in contemporary Europe. Int J Legal Med. 135(5):2033–2044. doi: 10.1007/s00414-021-02547-6.

Vucic S, Dhamo B, Jaddoe VWV, Wolvius EB, Ongkosuwito EM. 2019. Dental development and craniofacial morphology in school-age children. Am J Orthod Dentofacial Orthop. 156(2):229–237.e4. doi: 10.1016/j.ajodo.2018.09.014.

Weiliang Z, Wei W, Lili G. 2021. Comparative study of anthropometric nasal anslysis based on Han nationality young female adults in Central China. J Craniofacial Surg. 32(4):1455–1458. doi: 10.1097/SCS.0000000000007282.

Wen YF, Wong HM, McGrath CP. 2017. A longitudinal study of facial growth of Southern Chinese in Hong Kong: comprehensive photogrammetric analyses. PLoS One. 12(10):e0186598. doi: 10.1371/journal.pone.0186598.

Windhager S, Mitteroecker P, Rupić I, Lauc T, Polašek O, Schaefer K. 2019. Facial aging trajectories: a common shape pattern in male and female faces is disrupted after menopause. Am J Phys Anthropol. 169(4):678–688. doi: 10.1002/ajpa.23878.

Yeung CYC, McGrath CP, Wong RWK, Hägg EUO, Lo J, Yang Y. 2015. Frontal facial proportions of 12-year-old southern Chinese: a photogrammetric study. Head Face Med. 11(1):26. doi: 10.1186/s13005-015-0084-7.

Zhang X, Hans MG, Graham G, Kirchner HL, Redline S. 2007. Correlations between cephalometric and facial photographic measurements of craniofacial form. Am J Orthod Dentofacial Orthop. 131(1):67–71. doi: 10.1016/j.ajodo.2005.02.033.