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DIPLOMARBEIT

Digit Ratio (2D:4D) and Facial Shape in Adolescents –

The Lower the Ratio, the More Robust the Face?

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Abstract

In previous studies, measuring hormone levels from amniocentesis, a negative correlation of the testosterone to estrogen ratio in the amniotic fluid and the ratio of the lengths of the index finger and the ring finger, taken from the same individuals aged two years, was found. Therefore digit ratio (2D:4D) can be used as an indicator for the prenatal hormonal environment. A lower digit ratio, related to a higher prenatal testosterone level in the amniotic fluid, leads to a more robust and masculine face with male adults and children. In our study we examined the relationship between digit ratio and face shape with 77 adolescents 10 to 20 years of age. Therefore, photos of the faces, physical measurements, a questionnaire, and Geometric Morphometrics for shape analysis were used. Our hypothesis predicted that there was a correlation of digit ratio and facial shape with males and that a lower digit ratio leads to a more robust face with adolescent men. This hypothesis was partially confirmed. Shape regression of digit ratio on shape variables with right-handed adolescent men ($n = 22$) was not significant but changes in facial shape related to digit ratio were similar to these from male adults and children described in literature. This leads to the assumption that the relationship between digit ratio and facial robusticity, respectively masculinity is present from a very early time in ontogeny and not only activated during puberty. Possible reasons for the non-significant results are the small, heterogeneous sample of right handed males, the high correlation of facial shape and age with males, and our sample's age range which includes the period of puberty.

The facial patterns related to digit ratio found with adolescent females were different from the males' patterns on one hand and the shape changes found for young girls and adult women described in literature on the other hand. It was not possible to find an explanation for these patterns within our study.

Zusammenfassung

In bisher durchgeführten Studien konnte ein negativer Zusammenhang zwischen dem Verhältnis von Testosteron zu Östrogen in der Amnionflüssigkeit und dem Längenverhältnis von Zeige- zu Ringfinger, gemessen an denselben Individuen im Alter von zwei Jahren, gezeigt werden. Aus diesem Grund kann das Fingerlängenverhältnis (2D:4D) als Indikator für die pränatale hormonelle Umgebung in der Amnionflüssigkeit herangezogen werden. Ein niedrigeres Fingerlängenverhältnis, welches in Zusammenhang mit einem höheren pränatalen Testosteronlevel steht, führt bei männlichen Erwachsenen und Kindern zu einer robusteren und maskulineren Gesichtsform. In der vorliegenden Studie wurde der Zusammenhang zwischen dem Fingerlängenverhältnis und der Gesichtsform bei 77 Jugendlichen im Alter von 10 bis 20 Jahren untersucht. Dafür wurden Fotos von Gesichtern, anthropometrische Messungen, Fragebögen und Geometric Morphometrics zur Gestaltanalyse verwendet. Unsere Hypothese besagte, dass es bei jungen Männern einen Zusammenhang zwischen dem Fingerlängenverhältnis und der Gesichtsform gibt, und dass ein niedriges Fingerlängenverhältnis zu einer robusteren Gesichtsform bei jungen Männern führt. Diese Hypothese konnte teilweise bestätigt werden. Die Shape Regression vom Fingerlängenverhältnis auf die Gestaltvariablen war bei jungen, männlichen Rechtshändern ($n = 22$) zwar nicht signifikant, die mit dem Fingerlängenverhältnis einhergehenden Gestaltveränderungen im Gesicht waren jedoch vergleichbar mit den Ergebnissen bei männlichen Erwachsenen und Kindern in der Literatur. Das führt zu der Annahme, dass ein Zusammenhang zwischen dem Fingerlängenverhältnis und der Robustizität bzw. Maskulinität im Gesicht schon sehr früh in der Ontogenese vorhanden ist, und nicht erst während der Pubertät aktiviert wird.

Mögliche Gründe für die nicht signifikanten Ergebnisse sind die kleine und heterogene Stichprobe männlicher Rechtshänder, der starke Zusammenhang zwischen Gesichtsform und Alter bei Männern sowie die Altersspanne unserer Stichprobe, in welche auch der Zeitraum der Pubertät fällt.

Die Muster, welche bei weiblichen Jugendlichen in Zusammenhang mit dem Fingerlängenverhältnis beobachtet wurden, unterschieden sich sowohl von den bei Männern, als auch von den bei Mädchen und erwachsenen Frauen gefundenen Gestaltveränderungen im Gesicht und waren im Rahmen dieser Arbeit nicht interpretierbar.

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1 Introduction

Facial shape and facial proportions have been interesting topics for scientists and artists, especially painters (Rudolf Martin, Karl Saller, Albrecht Dürer) for a long time. Environmental and genetic factors are affecting face shape. For example there are effects on face shape related to age, sex, nutrition, and diseases (Fink, Neave & Manning, 2003). Furthermore there is a relationship between hormones and face shape. On one hand facial shape is related to the current level of testosterone, measured in the saliva, on the other hand there is an effect of prenatal testosterone (Schaefer, Mitteroecker, Fink & Bookstein, 2009) on face shape. As an indicator for the prenatal level of testosterone and estrogen, digit ratio of the second and the fourth digit can be used due to a correlation of children's digit ratios and the levels of estrogen and testosterone measured in the amniotic fluid with the same individuals (Lutchmaya, Baron-Cohen, Raggatt, Knickmeyer & Manning, 2004). Previous studies concerning digit ratio and face shape were done with adults and children (Fink et al., 2005; Schaefer et al., 2009; Meindl, 2009). In this study we examined a possible correlation of facial shape and digit ratio with 77 adolescents, aged 10 to 20 years using Geometric Morphometrics for Shape Analysis.

1.1 Human Growth

Human facial growth is allometric, which means that there are differences in intensity, direction and time of growth in various parts of the face. These findings are significant for males and females.

For males, mandibular and maxillary growth was measured from cephalograms of 30 participants at the age of 16, 18 and 20 years. Statistically significant rates of mandibular growth were found in both age intervals, 16 to 18 and 18 to 20 years. Growth was significant larger between 16 and 18 years. Mandibular growth was larger compared to maxillary growth in both age intervals. Furthermore a reducing of the mandibular plane angle and an upward and forward rotation of the mandible was observed (Love, Murray & Mamandras, 1990).

For females similar findings were shown. Mandibular and maxillary growth were measured from cephalograms of 37 participants at the age of 14, 16 and 20 years. Statistically significant rates of mandibular growth were found in both age intervals, 14 to 16 and 16 to 20 years, but reported to be lower than in males. According to findings for males, the mandibular growth was larger than

the maxillary growth in both age intervals, and the mandibular plane angle was reduced, which led to a closing rotation of the mandible (Foley & Mamandras, 1992).

As described for the face, there are also age related differences in growth velocity for various parts of the body.

A log-term study analyzing data of 50 females, with annual data acquisition from 6 to 15 years of age, found age dependent differences in growth. It was shown that the growth velocities of body height, maxilla, mandible and cranial base were different. While growth velocity in the maxilla was very high at the age of about 8 to 9 years, growth in body height, mandible and cranial base was considerable fast at the age of about 11 to 13 years (Figure 1, Baughan, Levesque & Lapalme-Chaput, 1979).

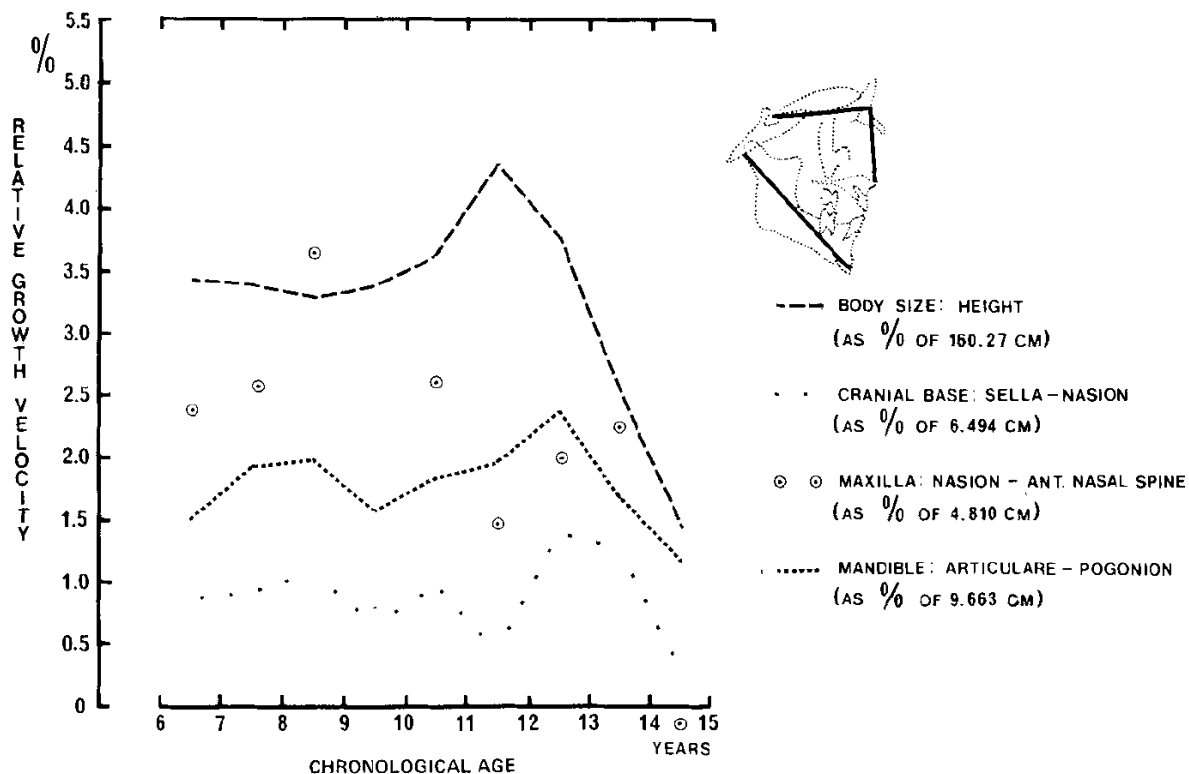


Figure 1. Growth velocity curves of body height, mandible, maxilla and cranial base for females aged 6 to 15 years. Maxilla shows a high growth velocity at the age of 8 to 9 years, body height, mandible and cranial base grow faster at the age of 11 to 13 years (Baughan et al., 1979).

For males and females differences in relationship between growth of radius and tibia and the peak height spurt in the years around puberty were found. Furthermore, elongation rate of the distal end of the femur was twice as high as elongation of the proximal end in the same period of time.

This means that there are differences in intensity and time of growth in various parts of the body and within single bones (review in Wales, 1998).

Anthropometric measurements from 301 children and adolescents aged 7 to 20 years showed that there are also age related differences in growth of body height. During puberty a growth spurt was observed, between 11 and 12 years for females and between 13 and 15 years for males. It is supposed that initiation of growth spurt is caused by an increased level of serum testosterone for boys and an increased level of plasma estrogen and estradiol for girls, which is reported to occur at the same age as the growth spurt (Krabbe, Christiansen, Rodbro & Transbol, 1979; after Gupta, 1975).

1.2 Face Shape in Children and Adults

Children's faces do not look like smaller adults faces but there are growth dependent differences in proportions and development of certain facial traits. Children's faces are vertically short because the nasal part of the face is small, corresponding to small lungs and respiratory ducts. Furthermore dentition, primary and secondary, is not yet fully developed and the jaw bones have not grown vertically. Therefore the forehead is higher compared to the lower face, bulbous and upright. The nose is short and rounded, the nasal profile is concave and the nasal bridge low. The face looks flat with a large distance between the eyes (Figure 2, Enlow & Hans, 1996).

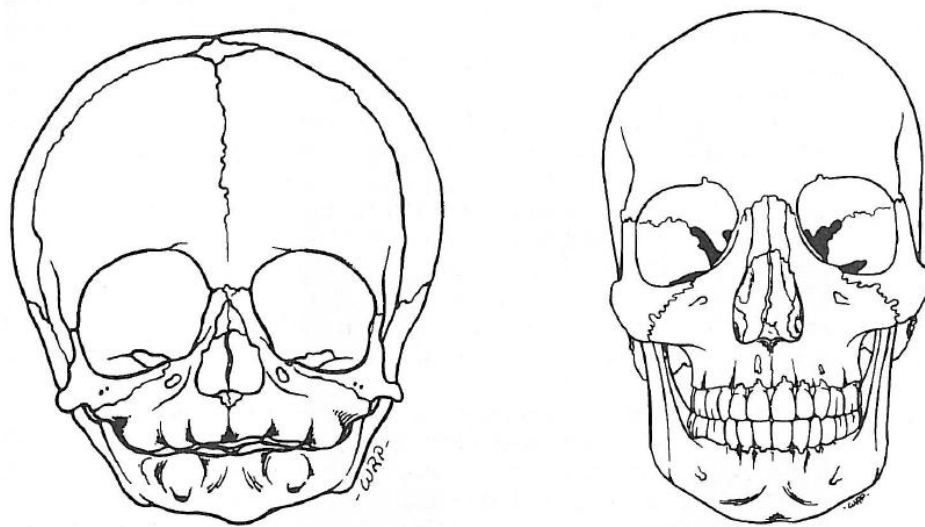


Figure 2. Differences in head and face shape between the child's and the adult's head. The child's forehead is higher compared to the lower face, formed bulbous and upright, the nose is short and rounded, the nasal profile is concave and the nasal bridge low (Enlow et al., 1996).

1.3 Sexual Dimorphism in Face Shape

The human face shape shows a distinct sexual dimorphism. Because of the bigger body height, men's lungs and respiratory ducts are also more voluminous than females'. Therefore men show a longer, broader and more protuberant nose than women, which is formed straight or convex. Men's nasal wings are bigger than women's. There are also sexual dimorphic differences concerning the shape of the forehead. Men show a back dragging, sloping forehead compared to the women's more vertical and bulbous front.

Due to the fact that women's faces are smaller, cheekbones seem to be more prominent than in males'. The chin is broader and more prominent in male as opposed to female faces (Figure 3, Enlow et al., 1996).

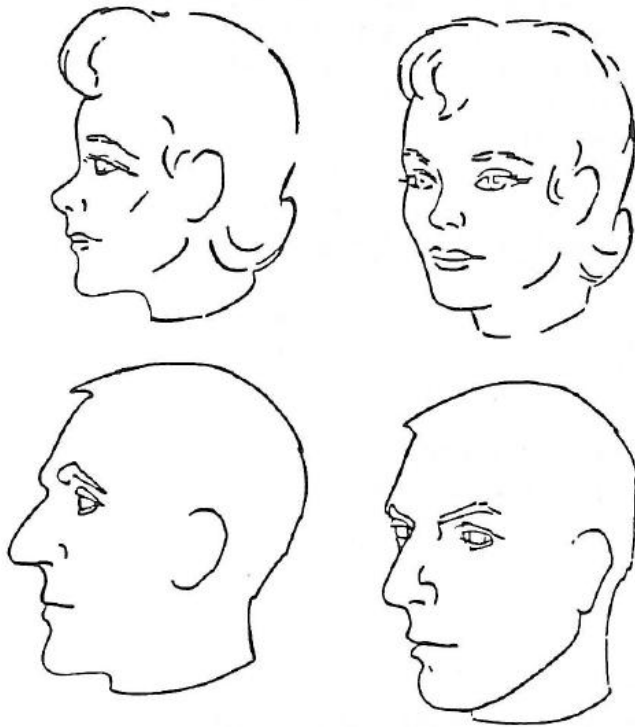


Figure 3. Sexual dimorphic differences of specific traits in male and female faces. Men's nose is longer, broader, more protuberant and formed straight or convex with bigger nasal wings than women's. Men's forehead is back dragging and sloping, the chin is broader and more protuberant than the women's. Women's forehead is more vertical and bulbous, the chin is smaller and the cheekbones seem more prominent than men's (Enlow et al., 1996).

1.4 Perceived Masculinity, Dominance and Attractiveness in Human Faces

2D:4D digit ratio and salivary testosterone were measured and photos of the faces taken from 48 male students, 18 to 33 years of age. The photos were rated from 36 female students, 19 to 30 years of age. They had to rate dominance, masculinity and attractiveness of the faces. Significant negative correlations were found for dominance respectively masculinity and digit ratio from the right and the left hand. There was no correlation found for salivary testosterone and any of the three qualities. Consequently males with a lower digit ratio, which is related to a higher level of prenatal testosterone, were rated as more dominant and more masculine. This strong correlation of digit ratio and male features leads to the assumption that high prenatal levels of testosterone organize male facial features which are activated during puberty and reflect dominance and masculine characteristics (Neave, Laing, Fink & Manning, 2003). Therefore it is possible that there are differences in perceived masculinity, dominance and attractiveness in faces of the same individuals as children, adolescents and adults. Being assessed wrong could lead to psychic problems for children and adolescents around the time of puberty.

In another study the variables salivary testosterone, 2D:4D digit ratio, body mass index (BMI) and perceived masculinity, dominance and attractiveness were shown as Principal Components of the corresponding shape vectors using singular value decomposition (SVD). First Principal Component showed face shape related to low BMI in one direction, and face shape correlating with measured testosterone (2D:4D) and perceived masculinity and dominance in the other direction. Second Principal Component showed face shape related to salivary testosterone on the one side and face shape related to perceived attractiveness on the other side. Third Principal Component showed the differences in face shape between biological and psychological variables. These results lead to the assumption that there are correlations of digit ratio, related to prenatal testosterone, and perceived masculinity and dominance. Furthermore it is shown that there are differences between salivary and prenatal testosterone and their influence on face shape (Schaefer et al., 2009).

Face and body photos of 92 American women (18 to 30 years of age) were rated by 60 American and Austrian men (19 to 55 years of age). With decreasing attractiveness the face lengthened, the nose became bigger, the chin more prominent and the lips smaller. High attractiveness correlated with a compression of the face visualizing grid, a rounder face shape, delicate nose, chin, and larger lips (Schaefer et al., 2006).

For males and females, facial attractiveness is related to youth, which reflects the absence of senescence, symmetry, which reflects developmental health and sexual dimorphic hormone markers, which in turn reflect hormonal health. Attractiveness is shown through honest signals and related to health. Therefore perceived facial attractiveness correlates with smooth and pliant skin, clear eyes and shiny hair (Thornhill & Gangestad 1999).

It can be supposed that human attractiveness evolved because of a preference for healthy and fertile mates in mate choice (Symons, 1979).

1.5 Sex-Hormone Markers in the Human Face

Some of the sexual dimorphic patterns in the human face are developed under the influence of sex hormones, especially estrogen and testosterone.

In males a high testosterone to estrogen ratio during puberty leads to broader cheekbones, a broader mandible and a broader chin. Furthermore the central face and the eyebrow ridges get more protuberant and the lower face gets longer (review in Thornhill & Gangestad, 1999).

A high estrogen to testosterone ratio in females caps the growth of areas that are large in males. Female jaws, chins and brow ridges are smaller, because the stage of growing in female faces is shorter than in male faces. Due to the smaller brow ridges female eyes appear larger than male eyes. Moreover lips and the upper cheek area get larger in female faces because of fat deposition (Thornhill & Gangestad, 1999; Thornhill & Gangestad, 2008; Thornhill & Grammer, 1999).

Sexual dimorphic hormone markers were also found in a study analyzing 376 young adults (188 males, 188 females). Nine feature points were placed on photos of their faces. Measuring distances and angles showed a sexual dimorphism in some traits of the faces. The upper lip height was higher in females than in males, but not statistically significant. The lower lip height was statistically significant higher in females than in males. Nose width was larger in males than in females, jaw angle was larger in females than in males (Burris, Little & Nelson, 2007).

1.6 Digit Ratio and its Measurement

2D:4D digit ratio describes the ratio of the length of the second and the length of the fourth finger. It is possible to directly measure finger lengths, at the inner side of the hands or indirectly from photocopies, radiographs or digital scans of the hands.

There are discussions about various measurement methods and their exactness and reliability.

Differences in 2D:4D digit ratio between direct finger length measurements and measurements from photocopies were found in a comparison of two measured values of the same individuals' fingers. The length of the second finger from photocopies was shorter or equal in length to the directly measured value whereas the length of the fourth finger was longer or equal in length to the directly measured value. Therefore values of digit ratios from photocopies were lower than ratios of directly measured finger lengths. Furthermore sexual dimorphism in digit ratio was more distinct in measurements from photocopies than in direct measurements. These sexual dimorphic differences between the two measuring modes could arise from fat pads in the finger tips, which are different between males and females (Manning, Fink, Neave & Caswell, 2005).

Comparing different studies concerning digit ratio, showed that the differences between finger lengths measured with and without tips, i.e. direct and from photocopies or from radiographs, were very small and strongly correlated (Galis, Ten Broek, Van Dongen & Wijnaendts, 2010).

In this study we decided to measure finger lengths direct, for a better practicability and comparability with recent studies done at our department.

1.7 Ethnic Differences in Digit Ratio

In a study measuring digit ratio of the right hand from 798 children, 90 Berbers, 438 Uygurs, 118 Han and 152 Jamaicans. Significant ethnic differences were found between all three groups of children. Digit ratio was highest for Han children, followed by the Berbers and Uygurs. The lowest digit ratio was found for the Jamaican children. There were no correlations found for digit ratio and age or body height (Manning, Steward, Bundred & Trivers, 2004). Due to these findings it seems to be reasonable to include the participants' origin in our study.

1.8 Digit Ratio and Prenatal Hormone Level

Due to a common genetic development of the fingers and the genito-urinary system there is a relationship between digit ratio in adults and the prenatal hormone level in the amniotic fluid of the same individuals. Homeotic genes (Homeox genes) are activated early in the human prenatal development. These control genes produce transcription factors, which activate gene cascades to regulate processes in the embryonic development like segmentation, specification and orientation of the segments (Sadler, 2008).

Two specific gene complexes, Hox a and Hox d, are relevant for a relationship between digit ratio and the prenatal hormone level. They control the differentiation of the genito-urinary system and therefore indirectly the prenatal production of testicular androgen. SRY, the sex determining region of Y which is located on the short arm of the Y chromosome, controls the development of the undifferentiated gonad and initiates male sex determination. Therefore testes are formed. Leydig cells arise from mesenchyme located near by the seminal duct and start to produce testosterone and androstendione from the thirteenth week of pregnancy. The influence of these hormones leads to a male differentiation of the mesonephric duct and the primary genitals (Moore & Persaud, 1998).

Furthermore HOX genes are important for the prenatal development of the appendicular skeleton including the fingers. Hence there is a correlation between the development of the fingers and the function of gonads and hormones (Lutchmaya et al., 2004).

To show the correlation of prenatal hormone level and digit ratio, hormone levels were measured from 33 healthy fetuses (18 males, 15 females) during routine amniocentesis. The hormones of interest were fetal testosterone (FT) and fetal estradiol (FE). A sexual dimorphism was found in the level of FT. Fetal testosterone concentration was significantly higher in male than in female fetuses. There was no significant difference between sexes found in the FE level. The ratio of FT and FE (FT:FE) revealed a significant higher value in males than in females.

Measurements of finger lengths were taken from the same individuals at the age of two years. Digit ratio was lower in males than in females, but not significant. Negative correlations of both hands and FT as well as correlations of both hands and FE were found, but not significant. There was a significant negative correlation of the FT:FE ratio and the 2D:4D digit ratio in both hands, but only significant in the right hand (Lutchmaya et al., 2004).

1.9 Sexual Dimorphism in Digit Ratio (2D:4D)

Measurements of early prenatal digit ratios showed, that the size ratios of hand bones in the thirteenth week of pregnancy are very similar to them in adulthood (Garn, Burdi, Babler & Stinson, 1975).

Measurements of hand width, hand length and finger lengths of the second and fourth digit were taken from 161 fetuses between the ninth and the fortieth week of pregnancy. Two Indices were computed. There was no significant difference found in the Hand-Index ($\text{Hand-Index} = [(\text{hand}$

width/hand length) * 100]) between sexes. Digit ratio (2D:4D) was significantly lower in male than in female fetuses. Digit ratio seems to be stable during pregnancy; there were no significant changes in digit ratio found in the observed period of time (Figure 4, Malas, Dogan, Evcil & Desdicioglu, 2006).

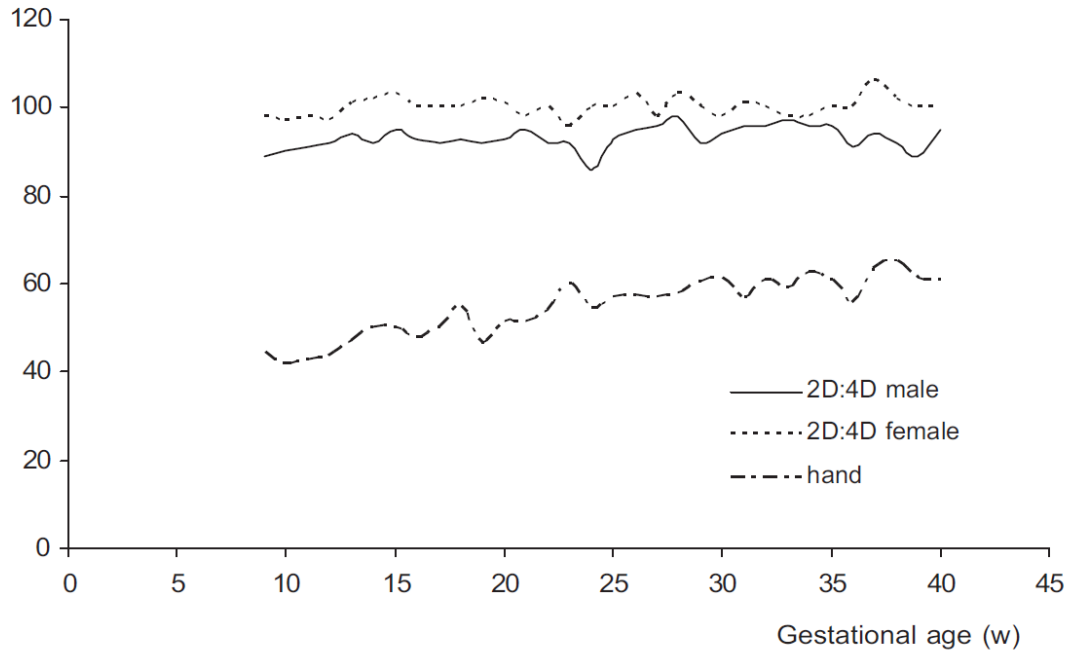


Figure 4. Digit ratio and hand index of males and females from tenth to fortieth week of pregnancy. Digit ratio [(length of the second digit/length of the fourth digit)*100] was significantly lower in males than in females. There was no significant difference between sexes in the hand index [(hand width/hand length) * 100]. The digit ratios of males and females did not show significant changes over the time of interest (Malas et al., 2006).

Another examination also found a sexual dimorphism present as of the fourteenth week of pregnancy (Galis et al., 2010).

Thus a sexual dimorphism in digit ratio seems to appear very early in human development.

Measurements of finger lengths were taken from 400 males and 400 females 2 to 25 years of age. Digit ratio (2D:4D) was lower in males than in females. The average digit ratio in males was 0.98 mm (range 0.86 – 1.2; s.d. = 0.002), in females it was 1.00 mm (range 0.88 – 1.15; s.d. = 0.002) in the right hand. This means that there was a sexual dimorphism in digit ratio. Males' second fingers were proportional shorter compared to their fourth fingers and females' second fingers

were of equal length or longer than their fourth fingers. There was a difference in the digit ratio of the left hand too, but not significant (Manning, Scutt, Wilson & Lewis-Jones, 1998).

Therefore we expect to find sexual dimorphic differences in digit ratio in our sample.

1.10 Digit Ratio and Age

Growth of the fingers in males and females is different in intensity and interval. An internet study with 47042 participants (20406 males, 26636 females) showed that at the age of 12 years, lengths of second and fourth digits were very similar. Afterwards male fingers grew faster and longer in time. While growth in females stopped at the age of about 17 years, male fingers reached their maximum length at the age of about 19 years (Figure 5, Manning, 2010).

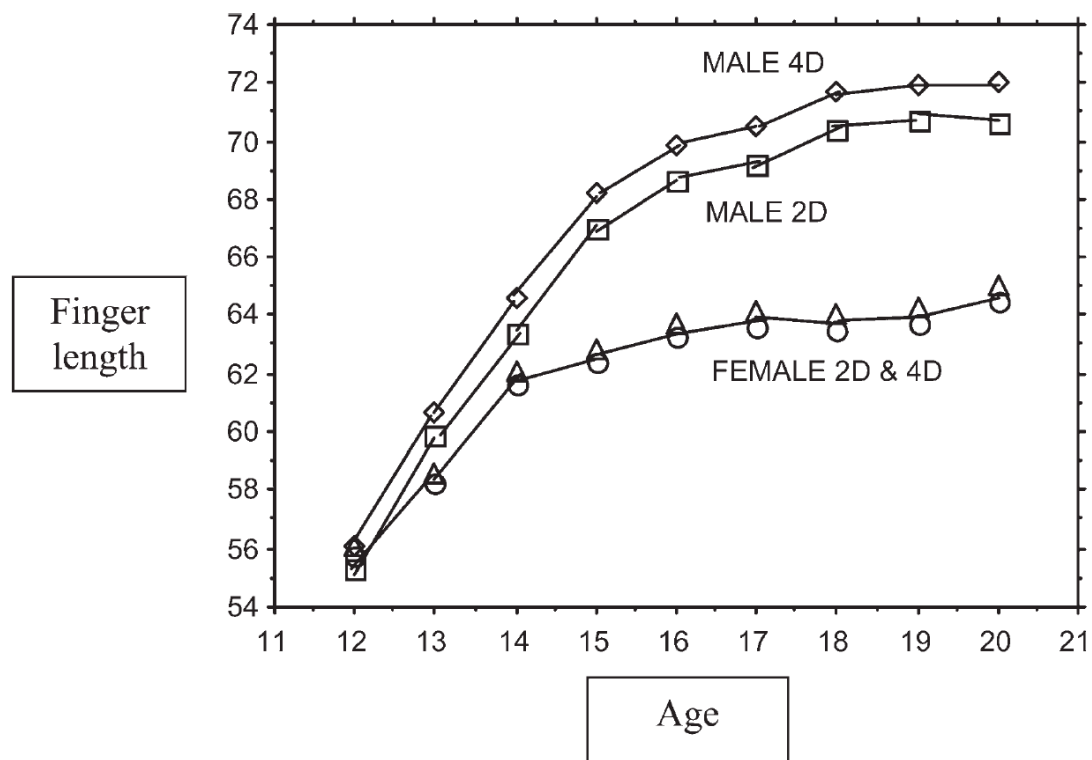


Figure 5. Positive correlation of finger length and age in males and females aged 12 to 20 years. Males' second and fourth digits showed a stronger growth in length that lasted about two years longer in time than females' (Manning, 2010).

Therefore the sexual dimorphism in finger lengths increased strongly from 12 to 19 years. Differences between sexes in digit ratio enlarged far less than finger lengths, but yet changed from a value of 1.004 at the age of twelve to 1.013 at the age of 20 (Figure 6, Manning, 2010).

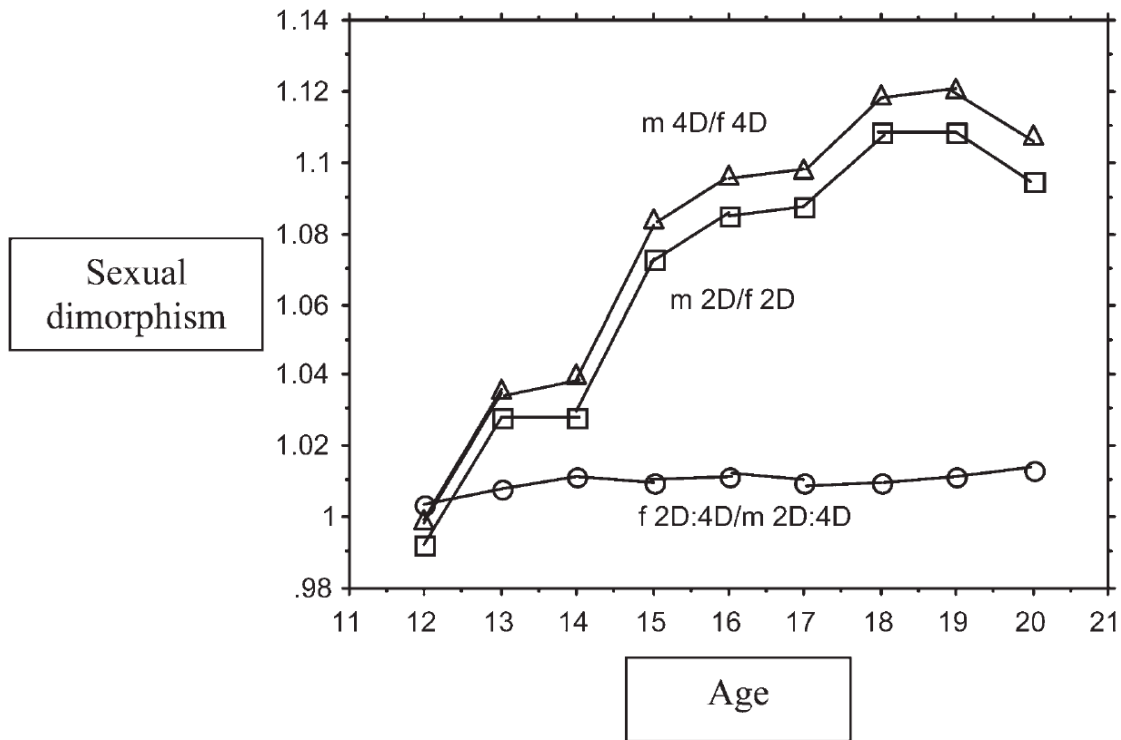


Figure 6. Age dependent differences in finger length ratios (male 4D/female 4D; male 2D/female 2D) and digit ratio (female 2D:4D/male 2D:4D) of the right hand. Sexual dimorphism of finger lengths increases stronger than sexual dimorphism of digit ratio between 12 and 20 years of age (Manning, 2010).

The age range of our sample (10 to 20 years) leads to the assumption, that differences in finger lengths and digit ratios can be found in different groups of age.

1.11 Different Research Topics in Connection with Digit Ratio (2D:4D)

Due to a correlation of finger lengths and the prenatal hormone level, digit ratio can be used as an indicator for the amount of prenatal present testosterone. Therefore digit ratio is of interest for a lot of completely different fields of research.

Digit Ratio and Behavior

Recent studies showed that a lower digit ratio, related to a higher level of prenatal androgens, leads to a more typical male behavior in both sexes (Breedlove, 2010).

Correlations of digit ratio and sexual orientation were found for males and females. Heterosexual men had a lower, i.e., more masculine digit ratio than homosexual men (Lippa, 2003) while homosexual women had a lower digit ratio than heterosexual women (Williams et al., 2000) and were sexually interested in other women more often than females with a higher digit ratio (Breedlove, 2010).

Comparing digit ratio and personality scores, measured through systemizing quotient (SQ) and empathizing quotient (EQ), negative correlations of digit ratio and SQ were found for males and females independent of age, body height, ethnic group and sexual orientation (Manning, Baron-Cohen, Wheelwright & Fink, 2010).

For men a negative correlation of digit ratio and aggression was found in a meta-analysis using 64 studies (Hoenekopp & Watson, 2011; Hoenekopp, 2011).

Negative correlations of digit ratio and risk taking were found for females in general (Hoenekopp, 2011) and for males in road traffic behavior (Schwerdtfeger, Heims & Heer, 2010). Digit ratio is also associated with cooperation (Sanchez-Pages & Turiegano, 2010), children's play behavior (Hoenekopp & Thierfelder, 2009) and developmental psychopathology in children (Fink, Manning, Williams & Podmore-Nappin, 2007) (for more details see Appendix A).

Digit Ratio and Diseases

Digit ratio (2D:4D) is associated with certain diseases. Therefore it can be used in medicine for early detection and diagnoses of these illnesses (Manning & Bundred, 2000).

A negative correlation was found for digit ratio and age of breast cancer occurring in women, which means that tumors appeared at a lower age in women with a higher digit ratio, related to a higher level of prenatal estrogen (Manning & Leinster, 2001).

Autism in children is associated with a lower digit ratio related to a higher level of prenatal testosterone (Manning, Baron-Cohen, Wheelwright & Sanders, 2001; Noipayak, 2009).

Digit ratio is also related to Congenital Adrenal Hyperplasia (CAH), a disorder of the adrenal gland, which often leads to a virilization of the patients (Griffin & Ojeda, 2000; Kleine & Rossmannith, 2010). Children and adults suffering from CAH showed lower digit ratios than healthy people (Brown, Hines, Fane & Breedlove, 2002; Oekten, Kalyoncu & Yaris, 2002).

A negative correlation was also found for digit ratio and Atherosclerosis, which means that people with atherosclerotic plaque present in the coronary artery showed lower digit ratios than healthy people (Ozdogmus et al., 2010) (for more details see Appendix B).

Digit Ratio and BMI, Hip and Waist Circumferences and WCR

Using 2D:4D digit ratio as an indicator for the amount of prenatal androgens, some correlations of digit ratio and physical traits were found (for summary see Table 3).

Anthropometric measurements of 120 students (50 males, 70 females) showed a positive correlation of digit ratio and BMI for males, significant only in the left hand. For females, negative correlations of digit ratio and waist circumference, hip circumference and waist to chest ratio (WCR) were found, significant for both hands. The relationships were stronger in female than in male participants (Fink et al., 2003).

1.12 Digit Ratio and Face Shape in Adults

Due to the fact, that face shape is related to sex hormones, a relationship between digit ratio (2D:4D) and face shape can be assumed.

Digit ratios were measured in 106 participants (50 males, 56 females), 18 to 38 years of age. According to previous studies a sexual dimorphism in finger lengths was found. Males had a significant lower digit ratio than females, i.e., males' second digits were shorter compared to their fourth digits while the second and fourth fingers in females were approximately equal in length. Furthermore photos of the participants' faces were taken to examine a possible correlation of digit ratio and face shape. A shape regression showed variation in face shape related to digit ratio. Participants with a lower digit ratio had smaller lips, broader jaws, broader zygomatic arches and broader chins. Higher digit ratios lead to fuller lips, smaller jaws, smaller zygomatic arches and smaller chins. This means that males (Figure 7) and females (Figure 8) with a lower digit ratio, which equals to a higher prenatal level of testosterone, had more robust faces than persons with a higher digit ratio. The regression of digit ratio on face shape was statistically significant for males. The effect was three times stronger than for females. With females the correlation was not clean and not statistically significant (Fink et al., 2005).

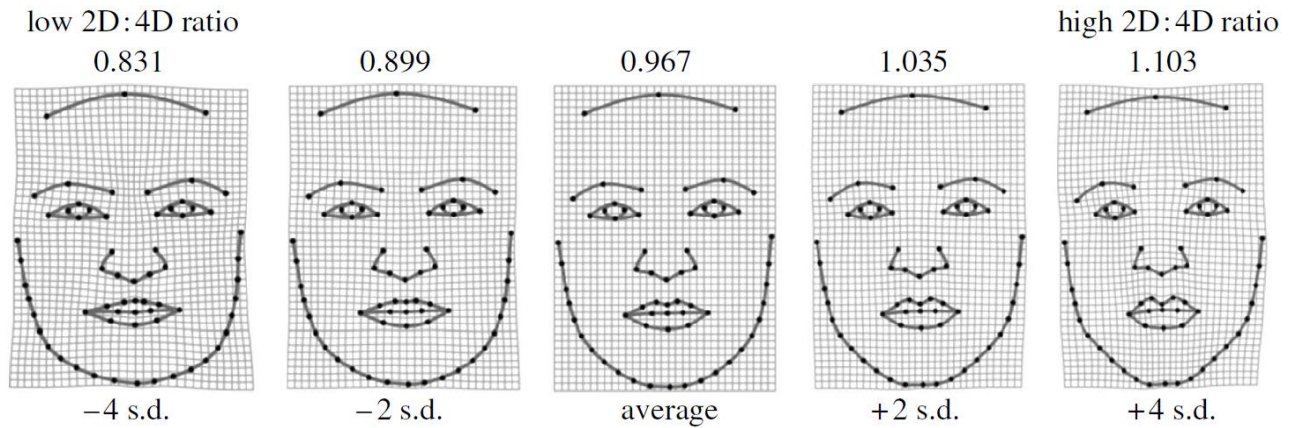


Figure 7. Deformation grids of shape regression for male faces and the average digit ratio of both hands. The intermediate grid shows the average face shape for all 50 faces. On the left side the shape variation related to a lower digit ratio is shown (2 s.d. and 4 s.d. lower than the average face). The two grids on the right side correspond to 2 s.d. and 4 s.d. higher digit ratios than the average face. Lower digit ratio, related to a high level of prenatal testosterone, leads to a more robust face (Fink et al., 2005).

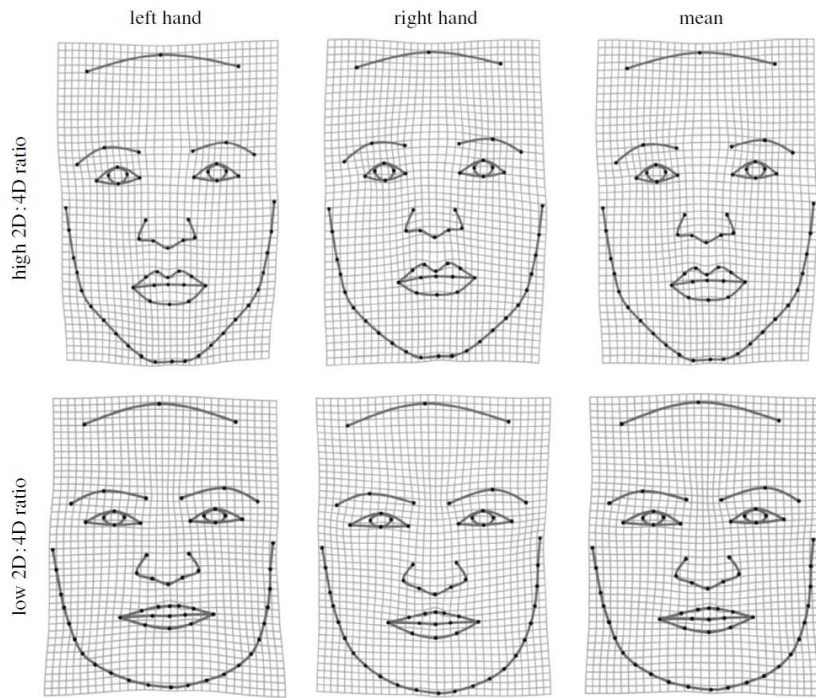


Figure 8. Deformation grids of shape regression for female faces and digit ratio divided into three groups. The three columns show the shape regression for digit ratios of the left hand, the right hand and the average digit ratio of both hands. The upper grids correspond to a digit ratio 6 s.d. higher and the lower grids to a digit ratio 6 s.d. lower than the average digit ratio. Low digit ratio, which is related to a high level of prenatal testosterone, leads to a more robust face. Patterns are very similar for digit ratio of the left and right hand and for the average digit ratio of both hands (Fink et al., 2005).

Similar results were found in another study using deformation grids to visualize changes in face shape related to digit ratio for males (original data published by Neave et al., 2003). Lower digit ratios, which are related to higher prenatal levels of testosterone, lead to smaller foreheads, smaller eyes, smaller distances between the eyes and between eyes and eyebrows, broader jaws, broader zygomatic arches and broader chins. Faces related to higher digit ratios had higher foreheads, larger eyes, larger distances between the eyes and between eyes and eyebrows, smaller jaws, smaller zygomatic arches and smaller chins (Schaefer et al., 2009).

1.13 Digit Ratio and Face Shape in Children

Digit ratios of the right hands were measured from 44 children aged three to eleven (20 males, 24 females) and compared to photos of their faces. With males, a statistically significant regression of digit ratio on face shape was found. Participants with a lower digit ratio showed a more robust face with a broader chin and more prominent eye brow ridges. With females, no significant correlation was found (Meindl, 2009).

1.14 Prenatal versus Pubertal Testosterone Level

It is important to consider the fact that there is a difference between prenatal and pubertal testosterone and their effects on face shape. To show the different relationships, testosterone levels were measured with 48 males (18 to 33 years) and compared to their face shapes. Digit ratio (2D:4D) was used as an indicator for the prenatal testosterone level, while the pubertal amount of testosterone was measured in the saliva.

Higher prenatal testosterone levels, implying lower digit ratios, lead to larger lower faces, broader zygomatic arches, and broader chins while a lower prenatal testosterone level was expressed in smaller lower faces, smaller chins and larger foreheads.

Whereas higher salivary testosterone levels lead to rounder faces with smaller eyebrows and smaller eyes, lower testosterone levels in the saliva resulted in longer faces with eyebrows lengthened to the middle and the sides of the faces (Schaefer, Fink, Mitteroecker, Neave & Bookstein, 2005).

Table 3. Correlations of digit ratio and physical traits.

Physical traits	Digit ratio (2D:4D)				
BMI	Males	Hand	Females	Hand	Reference
	pos. corr.	left	no corr.		Fink, 2003
Hip circumference					
	no corr.		neg. corr.	both	Fink, 2003
Waist circumference					
	no corr.		neg. corr.	both	Fink, 2003
WCR					
	no corr.		neg. corr.	both	Fink, 2003
Face shape					
Adults					
- More robust	lower 2D:4D	both	no. corr.		Fink, 2005
- More gracile	higher 2D:4D	both	no. corr.		
Children					
- More robust	lower 2D:4D	right	no. corr.		Meindl, 2009
- More gracile	higher 2D:4D	right	no. corr.		

1.15 Hypotheses

Digit Ratio and Face Shape in Adolescents

A statistically significant regression of digit ratio on face shape in adolescent males can be expected due to similar findings in previous literature about adults and children (Fink et al., 2005; Meindl, 2009). Low digit ratios in males, which are related to high levels of prenatal testosterone, expressed in more robust faces, smaller lips, broader jaws, broader zygomatic arches, broader chins and more prominent eye brow ridges (Fink et al., 2005).

For females no significant regression of digit ratio on face shape is expected, because there were no significant findings, neither in adults (Fink et al., 2005) nor in children (Meindl, 2009). Possibly females' deformation grids related to digit ratio will show similar patterns than males'.

2 Material and Method

2.1 Participants

Photos and measurements, collected by two students from the University of Vienna, were taken from 93 persons (31 males, 62 females). 15 photos were excluded to reduce variation in digit ratio due to the children's countries of origin. One more photo was excluded because of side rotation of the face. Three photos from another sample collected by a student at the University of Vienna in 2009 were added to increase sample size. The new sample contains 77 persons (27 males, 50 females), every participant with at least one parent born in Austria or both parents born in Central Europe (Table 4). The mean age of the sample was 15.00 years (range 10.33 – 20.17; s.d. = 2.803).

Table 4. Countries of origin of the participants' parents. They were born in 12 countries of Central Europe and 4 other countries.

Countries of origin (of the participants' parents)

Central Europe

- Austria
- Bosnia
- Bulgaria
- Croatia
- Germany
- Italy
- Kosovo
- Macedonia
- Poland
- Romania
- Serbia
- Slovakia

Other countries

- Mexico
- Sweden
- Tunisia
- Turkey

The participants were recruited from two Viennese schools, BRG XII Erlgasse and AHS II Kleine Sperlgasse.

After a short, age-appropriate talk about some topics of the diploma thesis and the procedure of the study during school lessons, information sheets (Appendix C) and declarations of consent (Appendix D) were handed out to all students to be signed by their parents or themselves, depending on the participants' age.

2.2 Procedure

2.2.1 Data Collection

Data collection was done in December 2010 and in January and February 2011. The testing took place in provided rooms at the schools mentioned above. For data acquisition, two students at a time were asked to leave class session for about 15 minutes.

2.2.1.1 Photos of the Faces

Color images were taken with a digital single lens reflex camera (Canon Eos 40D) placed on a tripod (Manfrotto). For all photos a flash was used. We took several photos of each person to select the best two of them for each face, one frontal and one lateral, from the left side of the face (for use in further studies). The distance between the camera objective and the face was kept constant at 3.55 m. The participants were sitting straight on a chair without touching the backrest in front of a grey colored background with the head orientated in the Frankfort horizontal position (Figure 9, Farkas, 1994). They were advised to put their hair out of the face and show neutral facial expression. One photo was taken with an ID number written on the board to organize the data in later analysis.

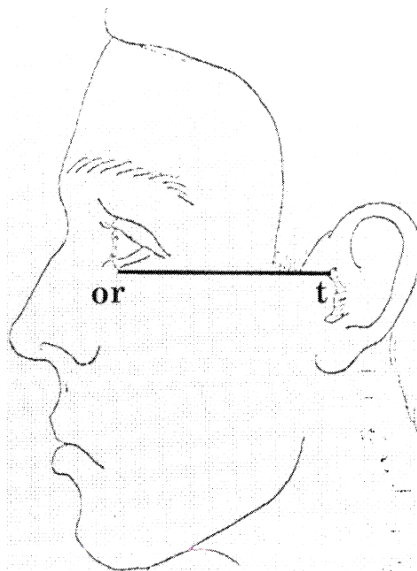


Figure 9 The Frankfort horizontal position. This means that the head is oriented horizontal along the line connecting the orbitale (or) and the porion (po) (Farkas, 1994).

2.2.1.2 Measurement of Finger Lengths (2D:4D)

The finger lengths from the second and fourth fingers of both hands were measured at the inner side of the hands (palmar) “from the tip of the finger to the ventral proximal crease” (Fink et al., 2005). Every measurement was taken twice, from the author and Karin Patocka, a colleague, to reach best possible reliability. The hand was positioned flat on a table during this process. For data acquisition we used a digital caliper (Helios DIGI-MET, accuracy: 0.01mm).

Digit ratio for the right hand (2D:4D right) was computed from the mean value of the two measurements of the second finger and the mean value of the two measurements of the fourth finger of the right hand

$$2D:4D \text{ (right)} = \frac{\text{value } (2D_{1R} + 2D_{2R})/2}{\text{value } (4D_{1R} + 4D_{2R})/2}$$

Digit ratio for the left hand (2D:4D left) was computed from the mean value of the two measurements of the second finger and the mean value of the two measurements of the fourth finger of the left hand

$$2D:4D \text{ (left)} = \frac{\text{value } (2D_{1L} + 2D_{2L})/2}{\text{value } (4D_{1L} + 4D_{2L})/2}$$

Mean digit ratio for both hands was computed as the arithmetic mean from 2D:4D right and 2D:4D left

$$2D:4D \text{ (mean)} = \frac{\text{value } (2D:4D \text{ right} + 2D:4D \text{ left})}{2}$$

2.2.1.3 Anthropometric Measurements

Body weight and body fat percentage were measured with a body fat scale (Tanita TBF 105), body height, waist and hip size were measured with an anthropometer and a measuring tape. Body Mass Index (BMI) and Waist to Hip ratio (WHR) were computed from these variables.

$$BMI = \frac{\text{body weight (kg)}}{[\text{body height (m)}]^2}$$

$$\text{WHR} = \frac{\text{waist size (cm)}}{\text{hip size (cm)}}$$

Here, as well, every measurement was taken on from two persons.

2.2.1.4 Facial Landmarks

Geometric Morphometrics

Traditional morphometrics operate with distances, ratios and angles measured between exactly defined points on bone or soft tissue. One downside of traditional morphometrics is the fact that there is no information about the locations of the reference points. A difference between measured distances tells us nothing about differences in the object's shape. Linear distance measurements, as used in traditional morphometrics, are often highly correlated with size. Therefore a shape analysis is quite difficult. Furthermore it is not possible to reconstruct graphic representations of the measured data (Slice, 2005).

But in biology shape, defined as “the geometric properties of an object that are invariant to location, scale and orientation” (Slice, 2005) is an interesting factor in a lot of questions. Diseases, ontogenetic development and evolution-forced adaptations are often correlated with changes of the individual or parts of the individual (Zelditch, Swiderski, Sheets & Fink, 2004).

In contrast to traditional morphometrics, in Geometric Morphometrics coordinates are used instead of distances ratios and angles. Therefore Geometric Morphometrics seems to be a very useful suite of methods for biological questions. The term Geometric Morphometrics describes methods for acquisition, processing and analysis of shape variables (Slice, 2005).

Landmarks are exactly defined points, which can be recognized on every individual of the study sample. There are three different types of landmarks, defined by Bookstein.

Type 1 landmarks, also called true landmarks, are located on exactly described points with biological significance, e.g., where three different bony or soft tissue structures come together.

Type 2 landmarks, also called pseudo-landmarks, are located at relative locations, for example curvature minima or maxima. Type 3 landmarks, also called semi-landmarks, are defined by

using other Type 1 or Type 2 landmarks, not by certain structures near or surrounding this point, e.g., the point midway between the most lateral and the most medial point of the eyebrow (Bookstein, 1991).

Landmarks can also be divided into fixed and sliding landmarks. Fixed landmarks are on exactly defined positions, for example the middle of the pupil or the lowest point of the chin. Sliding landmarks are usually located on curves, for example the chin curvature. They are allowed to slide along the tangents of these curves (Bookstein, 1991) to minimize either bending energy (Bookstein, 1996) or Procrustes distance (Bookstein, Streissguth, Sampson, Connor & Barr, 2002).

In our study we digitized 73 landmarks (after landmark definitions from Kolar & Salter, 1997 and Farkas, 1994, Table 5) on each of the 77 photos. 34 of 73 landmarks were defined to slide (Figure 10). Files for landmarks, curves, links and sliders were created with tpsUtil Version 1.46, the landmark digitization was done with tpsDig Version 2.16.

All TPS programs used in this study were written by F. James Rohlf (2009/2010), available online from <http://life.bio.sunysb.edu/morph/> (retrieved 2011). To reach high reliability, the digitization in our study was done from both students together.

Table 5. Landmark definitions and operationalization. An adapted landmark scheme from Kolar and Salter (1997) and Farkas (1994) with 39 fixed and 34 sliding landmarks.

Landmark definitions and operationalization
following Kolar and Salter (1997) and Farkas (1994)

Names of corresponding traditional anthropometric measurement points are in capitals, sliding semilandmarks in italics. “L[R]” describes bilateral measurement points; “M” marks landmarks on, or close to, the facial midline (that by definition have no right- or left-hand counterpart). (L is left, R is right, LM is landmark, M is midline)

Landmark (LM) definitions and operationalization for frontal photographs of faces approximating the Frankfurt horizontal plane

LANDMARKS

Forehead

1	M	VERTEX	highest point of the head when the head is oriented in the Frankfurt horizontal plane (Farkas 1994)
2	M	TRICHION	midpoint of the hairline, i.e. on the hairline through the midline of the forehead

Eyes and Eyebrows

3 [13]	L [R]	EXOCANTHION (ECTOCANTHION)	outer corner of the eye fissure where eyelids meet (most lateral visible point of the sclera)
4 [12]	L [R]	Top of the iris	highest visible point of the iris
5 [11]	L [R]	ENDOCANTHION	inner corner of the eye fissure where eyelids meet (on soft tissue slightly lateral to the bony Endocanthion)
6 [14]	L [R]	Bottom of the iris	lowest visible point of the iris
7 [17]	L [R]	Lateral iris	most lateral point of the iris
8 [16]	L [R]	Pupil	center of the pupil
9 [15]	L [R]	Medial iris	most medial point of the iris
10 [18]	L [R]		point on the border between Caruncula and Plica semilunaris, half way between upper and lower eyelid

Nose

19 [25]	L [R]	ALA ORIGIN (alar curvature point)	the lowest point of the curvature maximum of the nasal ala, the lateral flaring wall of the nostril
20 [24]	L [R]	ALARE	the most lateral point on each ala contour
21[23]	L [R]	COLUMELLA APEX	point of maximum concavity of the alar margin, in other words, highest point of the Columella crest at the apex of the nostril
22	M	SUBNASALE	midpoint of the angle at the columella base where the lower border of the nasal septum and the surface of the upper lip meet

Mouth

26 [32]	L [R]	CHEILON	located at the labial commissure; it is the outer corner of the mouth where the outer edges of the upper and lower vermilions meet
27 [31]	L [R]	<i>Upper lip point</i>	<i>digitized in the middle of Cheilon (LM 32 for the right side) and Crista philter (LM 30 for the right side) along the vermilion border before sliding</i>
28 [30]	L [R]	CRISTA PHILTER (CRISTA PHILTRI)	on each elevated margin of the Philtrum; it is the point on the crest of the Philtrum, the vertical groove in the median portion of the upper lip on the vermilion border
29	M	LABIALE SUP. (LABRALE SUP., LABRALE SUPERIOR)	the upper midpoint of the upper vermilion line, a point of maximum local curvature between the cristae philtri (LM 30 for the right side of the face)
37	M	STOMION	the imaginary point at the crossing of the vertical facial midline and the horizontal labial fissure between gently closed lips, with teeth shut in the natural position
34	M	LABIALE INF. (LABRALE INF., LABRALE INFERIOR)	the midpoint of the lower vermilion line, in other words, the lower local midpoint of the vermilion border of the lower lip

35 [33]	L [R]	Lower lip point	<i>local curvature maximum at the vermillion border of the lower lip on each side of the face between Cheilon (LM 32 for the right side of the face) and Labiale inferius (LM 34)</i>
36 [38]	L [R]	Labial fissure point	<i>exactly on the labial fissure half way between Cheilon (LM 26 of the right side of the face) and stomion (LM 37) before the sliding</i>

CURVES

Curve 1 Left Jaw

39	L	ZYGION	curvature maximum of the zygomatic arch
40-47	L	Jaw line	<i>eight landmarks equidistantly digitized between Zygion and Gnathion along the outline of the lower face before sliding</i>
48	M	GNATHION (MENTON)	turning point of right and left side of the chin; it is the lowest median landmark on the lower border of the mandible (along the jaw line)

Curve 2 Right Jaw

48	M	GNATHION (MENTON)	turning point of right and left side of the chin; it is the lowest median landmark on the lower border of the mandible (along the jaw line)
49-56	R	Jaw line	<i>eight landmarks equidistantly digitized between Zygion and Gnathion along the outline of the lower face before sliding</i>
57	R	ZYGION	curvature maximum of the zygomatic arch

Curve 3 Upper Eyebrow left

58	L	SUPERCILIARE LATERALE	the most lateral point of the eyebrow
59-61	L	Upper eye brow	<i>three landmarks equidistantly spaced along the upper rim of the eyebrow between LM 58 and 62 before sliding</i>
62	L	SUPERCILIARE MEDIALE	the most medial point of the eyebrow

Curve 4 Lower Eyebrow left

62	L	SUPERCILIARE MEDIALE	the most medial point of the eyebrow
63-65	L	<i>Lower eye brow</i>	<i>three landmarks equidistantly spaced along the lower rim of the eyebrow between LM 62 and 58 before sliding</i>
58	L	SUPERCILIARE LATERALE	the most lateral point of the eyebrow

Curve 5 Upper Eyebrow right

66	R	SUPERCILIARE MEDIALE	the most medial point of the eyebrow
67-69	R	<i>Upper eye brow</i>	<i>three landmarks equidistantly spaced along the upper rim of the eyebrow between LM 66 and 70 before sliding</i>
70	R	SUPERCILIARE LATERALE	the most lateral point of the eyebrow

Curve 6 Lower eyebrow right

70	R	SUPERCILIARE LATERALE	the most lateral point of the eyebrow
71-73	R	<i>Lower eye brow</i>	<i>three landmarks equidistantly spaced along the lower rim of the eyebrow between LM 70 and 66 before sliding</i>
66	R	SUPERCILIARE MEDIALE	the most medial point of the eyebrow

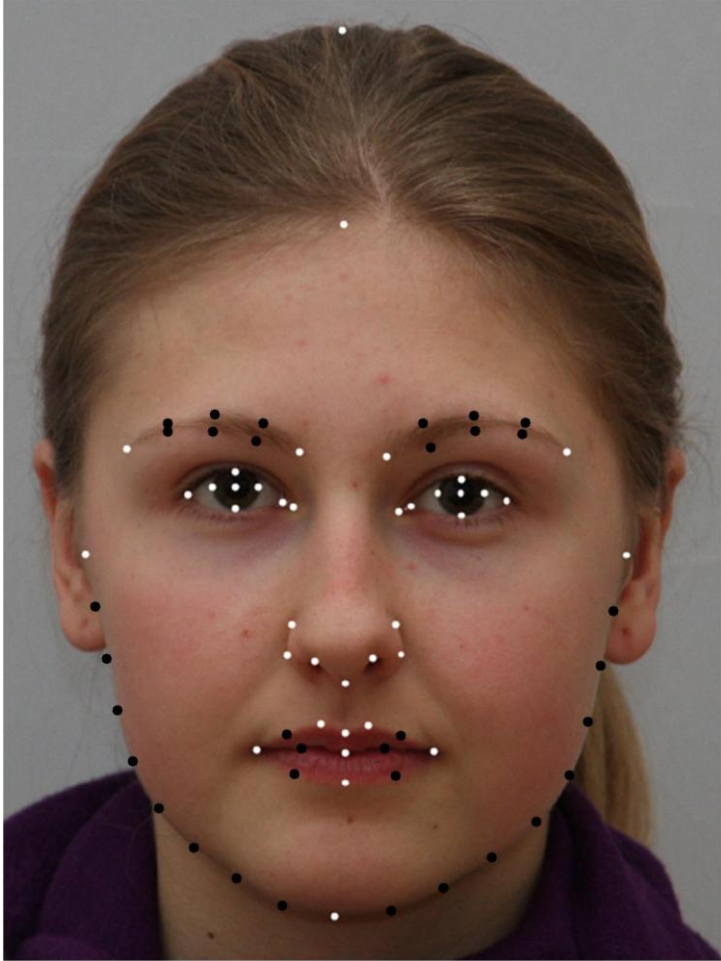


Figure 10. Positions of the landmarks on the face. 73 landmarks, 39 fixed (colored white) and 34 sliding (colored black), were placed on 77 faces following the adapted landmark definitions from Kolar et al. (1997) and Farkas (1994).

2.2.2 Questionnaire

A questionnaire was used to get information about the date and place of data acquisition, the participants' age, sex, handedness and injuries of fingers and face and also the taking of hormone preparation. Due to ethnic differences in digit ratio found in traditional literature (Manning et al., 2004), we asked the participants to indicate their parents' countries of origin (Appendix E and F).

2.3 Statistical Analysis

2.4 Descriptive Statistics

Descriptive Statistics was done with SPSS 17.0. T-tests were conducted to examine sexual dimorphism in digit ratio and finger lengths, differences in digit ratio related to handedness, and differences in finger lengths and digit ratio between older and younger participants. Pearson correlation was done for age and digit ratio respectively finger lengths, and for digit ratio and age, body weight, body mass index, waist circumference, hip circumference, waist to hip ratio, and body fat.

2.5 Analysis of the Landmark Coordinates

2.5.1 Generalized Procrustes Analysis (GPA)

Raw landmark data differs in size, orientation and location. Procrustes superimposition is used to minimize differences between the configurations of the data by minimizing the summed squared distances between corresponding landmarks of each specimen and a consensus configuration. Therefore one arbitrary specimen is selected to stand for the mean. All the other configurations are fit to the centroid of that reference specimen by removing differences in rotation, scale and orientation. Afterwards a new mean, the arithmetic average location of the individual landmarks in the sample, is computed and all other configurations are scaled to unit centroid size. In an iterative process this procedure is repeated many times and causes a monotonically decreasing sum of squared deviations of all configurations around an estimated mean. When the change in mean estimate and the decreasing of the sum of squares goes below a critical value between two following iterations, the procedure is stopped (Gower, 1975; Zelditch et al., 2004; Slice, 2007).

The now superimposed landmark coordinates are shape variables, geometric variables that are invariant to position, orientation and isometric size. Landmark configurations of all specimens are in one coordinate system. Therefore differences between coordinate values are differences in configurations' shapes (Slice, 2007). In our study we did General Procrustes Analysis in order to examine differences in face shape of adolescents. For GPA Morphologika Version 2.5 was used.

2.5.2 Thin Plate Spline (TPS)

For visualization of our sample data we used Thin Plate Spline which is a model of a thin metal plate. Shape differences between specimens can be shown as a deformation of the metal plate. Shape changes between landmarks can also be shown by taking all displacements of all landmarks relative to all others into account (Zelditch et al., 2004).

With Thin Plate Spline it can be examined where and in which directions shape changes occur. Changes in shape can also be visualized enhanced, for example + 3 s.d., to make small effects of independent variables on shape visible (Figure 11). We used Thin Plate Spline to visualize the effects of independent variables like age, sex and digit ratio on face shape in adolescents. Computations were done in tpsRegr Version 1.37.

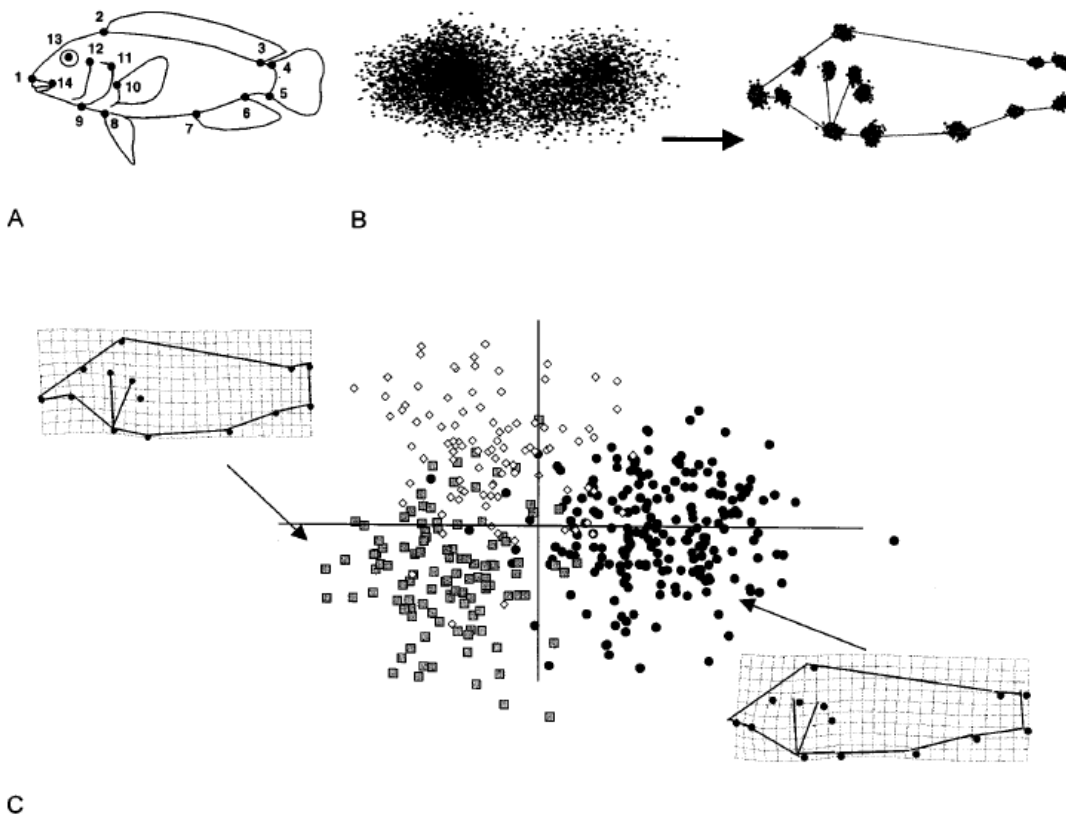


Figure 11 The different steps of data analyzing with Geometric Morphometrics. Part A shows the locations of the landmarks digitized for every specimen of the sample. On the left side of part B the raw landmark data can be seen before and on the right side after General Procrustes Analysis. Part C shows the statistical analysis (CVA) and a graphical representation of variation on deformation grids (Thin Plate Spline) (after Adams, Rohlf & Slice, 2004; data from Rüber & Adams, 2001).

2.5.3 Principal Component Analysis (PCA)

Morphometric variables of organisms are usually linked to each other because of their function, ontogenetic development or genetic determination. Therefore correlations of certain variables are difficult to explain. In Principal Component Analysis original variables are replaced by Principal Components (PCs). Principal Components are linear combinations of the complex original variables that are independent of each other, which is why different variation patterns can be explained much more easily with Principal Component Analysis. First Principal Component describes the variable which explains most of the shape variables' variation in percent of the total shape variation. Due to the fact that usually most of a sample's variation can be explained in a few Principal Components, interpretation of correlations is much easier with Principal Component Analysis (Zelditch et al., 2004). When data consists of shape variables, Principal Components are called Relative Warps (Slice, 2005). In our study Relative Warp Analysis was used for data control to find out if the scatter plot of our data was homogenous, if there were any outliers, and if our sample was comparable to others described in traditional literature. For this we used Morphologika 2.5 and tpsRelw Version 1.49.

2.5.4 Shape Regression

Shape regression is one method that is used with the hypothesis that a continuously valued factor, for example age, affects an object's shape. In regression, the variation in one variable, for example shape, is explained by another, for example age (Zelditch et al., 2004). In our analysis we regressed shape upon age and digit ratio in order to study the effect of digit ratio and age on facial shape in adolescents. For Shape Regression we used tpsRegr Version 1.37.

2.5.5 Reliability Analysis

To test reliability of digitizing landmarks, five photos (three girls, two boys) of our sample were chosen at random, and each one digitized five times from the same person. Then a relative warp analysis of all 77 faces additionally 25 digitized for reliability analysis was done. A scatter plot of the scores for the first and second relative warp can be used to estimate reliability in digitizing landmarks. Reliability is high, if the distances between all landmark configurations for one face in the scatter plot are smaller than the distances between these configurations and configurations

of other faces (O'Higgins & Jones, 1993; Figure 12). For our data, the scatter plot shows that the distances between the faces digitized for reliability analysis were smaller than the distances to other faces of the sample, which means high reliability. Whereas the distances between landmark configurations of the faces digitized for reliability analysis and the same faces digitized for shape analysis were larger, i.e., reliability was lower. This lower reliability is caused by adaptations of some landmark definitions, done after reliability analysis.

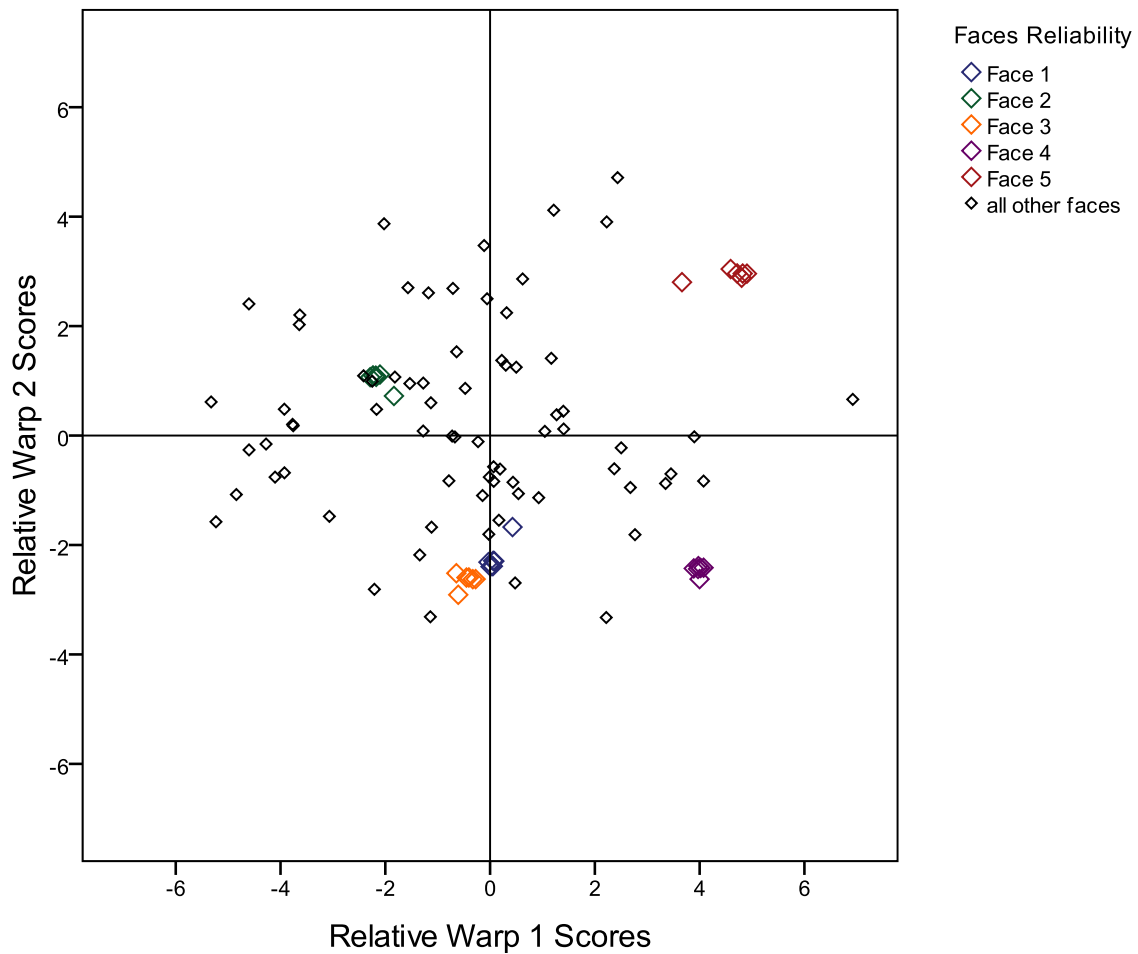


Figure 12. Scatter Plot showing the scores of Relative Warp 1 and Relative Warp 2 for all faces of our sample and 25 more landmark configurations of five digitized faces, each one digitized five times for reliability analysis. The colored diamonds show Relative Warp scores for the five faces used for reliability analysis, the black diamonds are all other faces of the sample. Due to an adaptation of landmark definitions after reliability analysis, landmark configurations digitized for reliability analysis are positioned nearer to each other than landmark configurations digitized for reliability analysis and the configuration of the same face used for shape analysis.

3 Results

3.1 Descriptive Statistics and Potentially Confounding Variables

The sample used for evaluation consists of 77 participants (27 males, 50 females) with a mean age of 15.00 years (range 10.33 – 20.17; s.d. = 2.82). 48 persons' parents were both born in Austria, 13 persons have one parent born in Austria and one from another country and the parents of 16 persons are both from another country in Central Europe that is not Austria.

All in all there are 13 left handed persons, 5 males and 8 females. For results of digit ratios see Table 6.

Table 6. Digit ratios of the right and left hand and mean digit ratio of both hands for males and females

Results - Digit ratios

Digit ratio	Mean	Standard Deviation
2D:4D right		
- males	0.9785	0.03150
- females	0.9831	0.03418
2D:4D left		
- males	0.9815	0.03527
- females	0.9957	0.02721
2D:4D mean		
- males	0.9800	0.03078
- females	0.9894	0.02808

Sexual Dimorphism in Digit Ratio and Finger Lengths

As shown in Table 6, there are differences between sexes in all three computations of digit ratio. Males' digit ratios are lower than females'. That means that men have a relatively shorter second digit compared to their fourth digit than women. A T-test was done to find out if these sexual dimorphic differences in digit ratio were significant. Differences between sexes in digit ratio of the right hand ($T = -0.577$; $p = 0.565$) and mean digit ratio of both hands ($T = -1.354$; $p = 0.108$) failed significance of 5%. Sexual dimorphic difference in digit ratio of the left hand was nearly significant ($T = -1.965$; $p = 0.053$).

In a second T-test only participants aged 12 to 20 years were included to find out if there are differences in sexual dimorphism of digit ratio related to age. A significant sexual dimorphic

difference was found in digit ratio of the left hand ($T = -2.322$; $p = 0.042$). Digit ratio of the right hand ($T = -0.998$; $p = 0.323$) and mean digit ratio of both hands ($T = -1.778$; $p = 0.081$) failed significance of 5%.

Sexual dimorphism in finger lengths was examined and significant differences between sexes found for all participants' right second fingers ($T = 6.875$; $p < 0.001$), left second fingers ($T = 7.440$; $p < 0.001$), right fourth fingers ($T = 7.571$; $p < 0.001$) and left fourth fingers ($T = 7.475$; $p < 0.001$).

Digit Ratio and Handedness

There were no significant differences found in digit ratio between right- and left-handed participants (2D:4D right: $T = -0.944$; $p = 0.348$; 2D:4D left: $T = -0.398$; $p = 0.692$; 2D:4D mean: $T = -0.744$; $p = 0.459$).

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Age and Digit Ratio and Finger Lengths

The Pearson correlation was not significant for digit ratio and age for the total sample (2D:4D right: $r = 0.091$; $p = 0.433$; 2D:4D left: $r = 0.124$; $p = 0.282$; 2D:4D mean: $r = 0.117$; $p = 0.311$), males (2D:4D right: $r = -0.044$; $p = 0.828$; 2D:4D left: $r = 0.007$; $p = 0.972$; 2D:4D mean: $r = -0.018$; $p = 0.927$) or females (2D:4D right: $r = 0.139$; $p = 0.336$; 2D:4D left: $r = 0.165$; $p = 0.253$; 2D:4D mean: $r = 0.164$; $p = 0.254$). A T-Test was done to find out if there were significant differences in digit ratios between older and younger participants. The sample was split at the age of 15.00 years, which represents the arithmetic mean and the median of the sample. No significant differences were found in digit ratio of the right hand ($T = 0.395$; $p = 0.694$), the left hand ($T = 0.559$; $p = 0.578$) or the mean value of both hands ($T = 0.519$; $p = 0.605$) between older and younger persons. However, it was observed that in males, digit ratio did not change over the time while in females, digit ratio increased with higher age (not significant).

Significant correlations were found for the total sample and the right second finger ($r = 0.465$; $p < 0.001$), the left second finger ($r = 0.454$; $p < 0.001$), the right fourth finger ($r = 0.408$; $p < 0.001$) and the left fourth finger ($r = 0.366$; $p < 0.001$). For males, correlations were also significant for age and the right second finger ($r = 0.879$; $p < 0.001$), the left second finger ($r = 0.858$; $p < 0.001$), the right fourth finger ($r = 0.837$; $p < 0.001$) and the left fourth finger ($r = 0.787$; $p < 0.001$). There was no significant correlation of age and finger lengths found for females (right second finger: $r = 0.270$; $p = 0.058$; left second finger: $r = 0.270$; $p = 0.058$; right fourth finger:

$r = 0.187$; $p = 0.194$; left fourth finger: $r = 0.169$; $p = 0.241$). Observed growth of fingers between 10 and 20 years of age was stronger in males than in females. That means that sexual dimorphism in finger lengths increased with higher age (Figure 13).

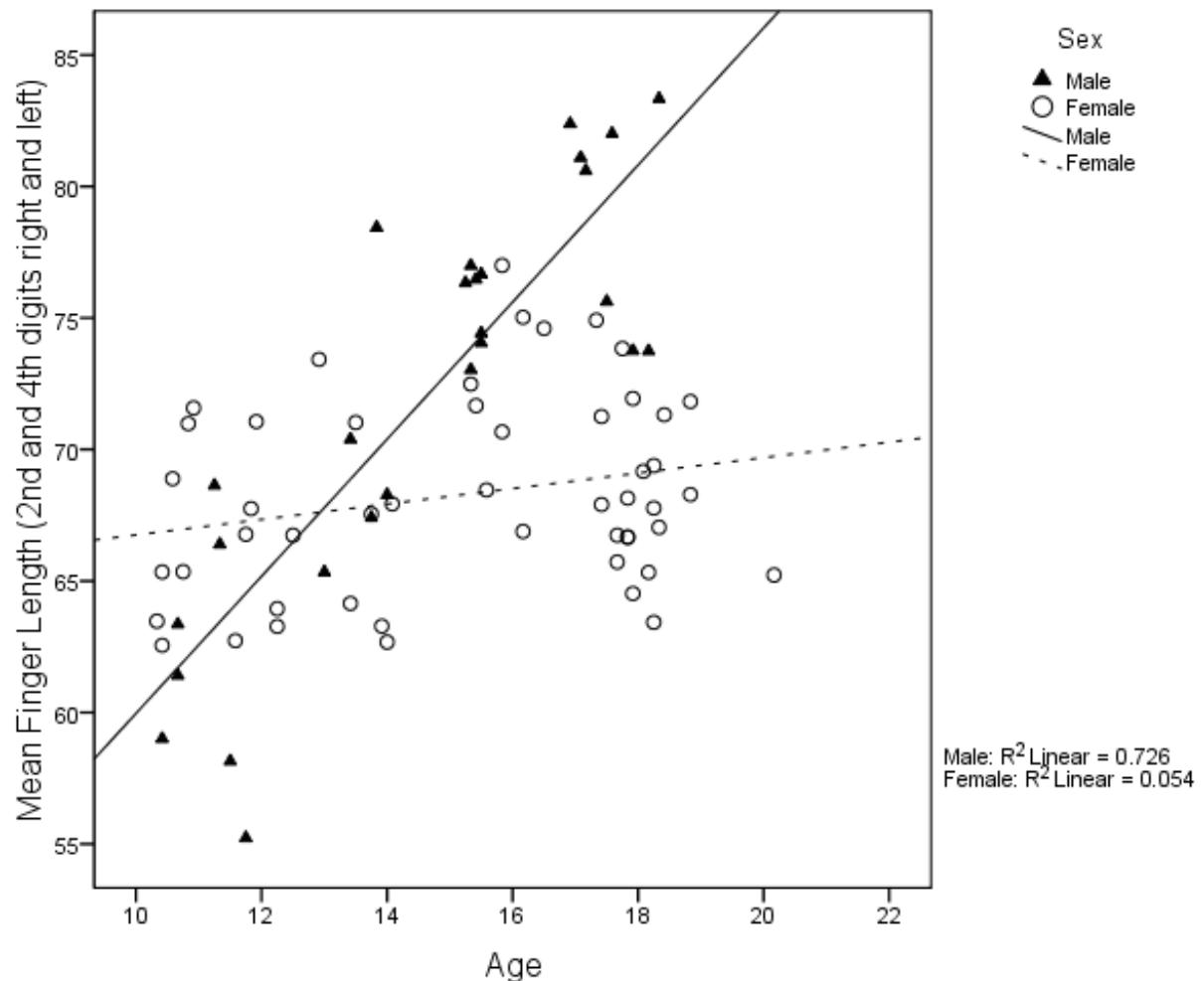


Figure 13. The arithmetic mean of the lengths of the left second finger, the right second finger, the left fourth finger and the right fourth finger was calculated and correlated with age of male and female participants. Males' finger lengths increased more than females'.

Digit Ratio and Other Independent Variables

Our hypothesis predicts that there is a correlation of digit ratio and face shape in adolescents. Before examining this relationship it is important to find out if there are correlations of digit ratio and other measured independent variables, to make sure that face shape and digit ratio are compared, and not face shape and another independent variable that is related to digit ratio.

Pearson correlation was not significant for any independent variable (age, body weight, body mass index (BMI), waist circumference, hip circumference, waist to hip ratio (WHR) or body fat), and digit ratio in males, females, or both sexes together.

3.2 Digit Ratio and Face Shape

Principal Component Analyses (PCA)

Principal Component Analysis was done for all participants and for the split sample (males and females).

Table 7. Values of the first, second, third and fourth Principal Component of facial shape for the total sample, males and females. PC values describe the explained variance in % of the total variance in face shape.

PC values for Principal Component Analysis (explained variance in % of total variance)

Principal Component	All participants	Males	Females
PC 1	24.4	27.0	25.2
PC 2	14.9	16.0	16.2
PC 3	12.6	10.6	10.1
PC 4	6.81	8.46	6.95

For all participants first Principal Component explains 24.4%, second Principal Component explains 14.9%, third Principal Component explains 12.6%, and third Principal Component explains 6.81% of the total face shape variance.

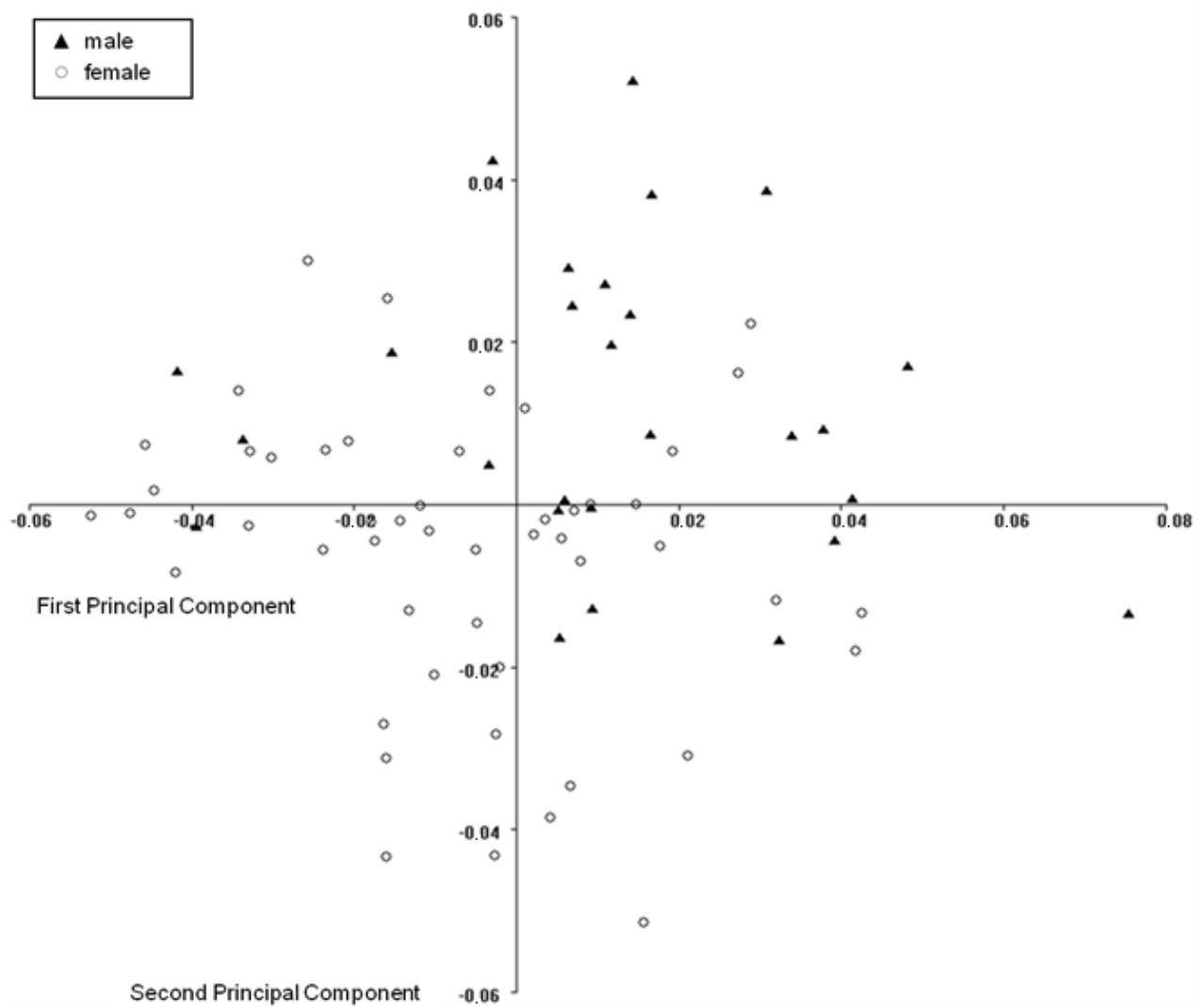


Figure 14. Scatter Plot of the first and second Principal Component of males' and females' facial shape. First Principal Component explains 24.4 % of the total shape variance, second Principal Component explains 14.9 % of the total shape variance.

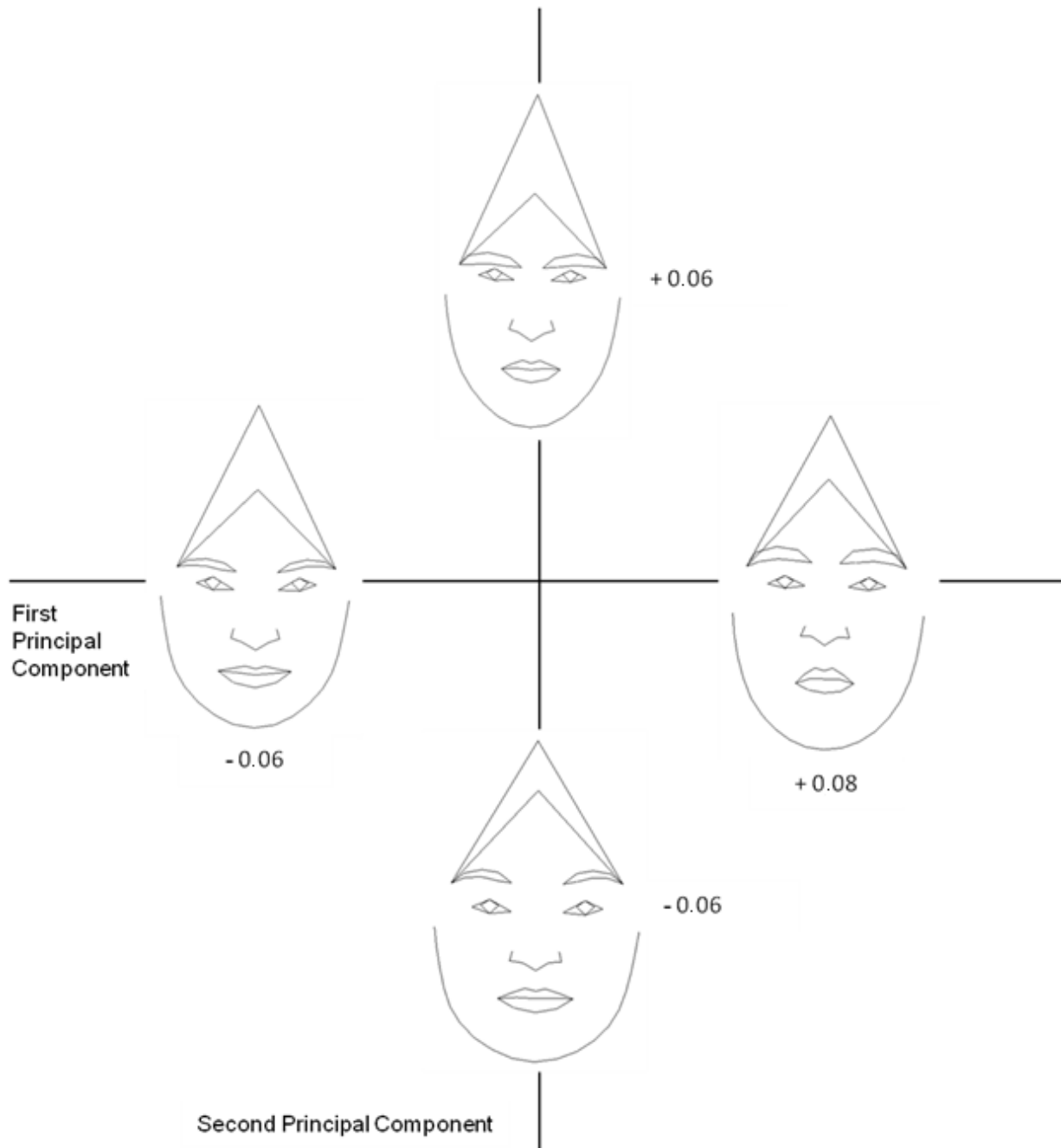


Figure 15. Variation in facial shape along the first and second Principal Component. The left and right faces, related to the first Principal Component, show differences in the lower face which is smaller and broader in the left than in the right face. Eyebrows are developed stronger and the lips are smaller in the right face. The face above the x-axis along the second Principal Component shows a higher forehead and a narrower lower face. Eyebrows are developed stronger and lips are narrower in the face below the x-axis.

Figure 14 shows the face shape related distribution of male and female participants along the first and second Principal Component. Most males are in the upper right and most females in the lower left quadrant. Vertical and horizontal sex related differences are observed. There are more males above the x-axis, representing the first Principal Component and on the right side of the y-axis, showing shape variation along the second Principal Component. Females are positioned below the x-axis and on the left side of the y-axis.

Figure 15 shows changes in face shape along the first and second Principal Component. The left grid shows a broader and smaller lower face compared to the right grid. Furthermore, the eyebrows are stronger developed and the lips are smaller in the right face. The chin seems to be higher in the right as opposed to in the left grid. Comparing the grids above and below the x-axes, there are changes in facial proportions. The face above the x-axis shows a higher forehead and a narrower lower face. Eyebrows are stronger developed and lips are narrower in this grid than in the one below the x-axis.

Table 8. Significant correlations of the first and second Principal Component and the independent variables body fat, waist to hip ratio, digit ratios of the right and left hand and mean digit ratio of both hands for all participants.

Correlations of Principal Components and independent variables (for all participants)

Principal Component	Independent variable	Correlation coefficient (Pearson)	Significance
PC 1	body fat	-0.248	0.033
PC2	body fat	-0.298	0.010
	waist to hip ratio	+0.278	0.017
	2D:4D right	-0.251	0.028
	2D:4D left	-0.237	0.038
	2D:4D mean	-0.267	0.019

Significant correlations for all participants were found for the first Principal Component and body fat ($r = -0.248$; $p = 0.033$) and for the second Principal Component and body fat ($r = -0.298$; $p = 0.010$), the second Principal Component and waist to hip ratio (WHR), the second Principal Component and digit ratio of the right hand ($r = -0.254$; $p = 0.028$), the second Principal

Component and digit ratio of the left hand ($r = -0.237$; $p = 0.038$) and the second Principal Component and mean digit ratio for both hands ($r = -0.267$; $p = 0.019$).

A T-Test and a regression (ANOVA) were done to find out if there was a relationship between Principal Components and the participants' sex. Significant results were observed for sex and first Principal Component ($T = 3.306$; $F = 10.929$; $p = 0.001$), sex and second Principal Component ($T = 4.177$; $F = 17.446$; $p < 0.001$) and sex and third Principal Component ($T = -2.433$; $F = 5.922$; $p = 0.017$). There was no significant relationship found between sex and fourth Principal Component ($T = 1.487$; $F = 2.211$; $p = 0.141$).

Shape Regression

Regression of independent variables on shape showed how much of the variance in face shape can be explained with one independent variable. Shape regression was done with digit ratio and age. Thin Plate Spline was used to visualize changes in face shape. A permutation test (10000 permutations) was used to control significance ($p \leq 0.05$).

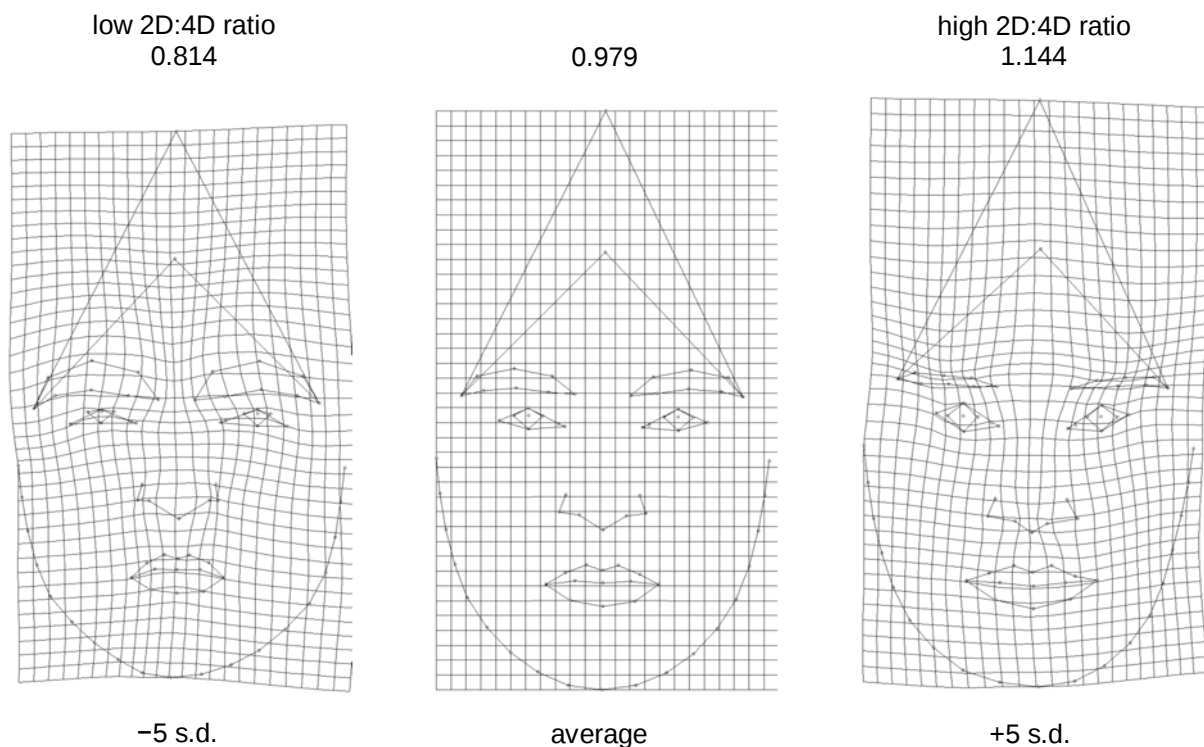


Figure 16. The central grid shows the average configuration for the mean digit ratio of both hands from right handed males ($n = 22$). On the left grid, shape changes related to low digit ratio are visualized; the right grid shows the face shape characteristic for a high digit ratio (both deformations 5 s.d. enhanced).

The explained variance of shape variation through mean digit ratio of both hands from right handed males is 6.0511%. Permutation test failed significance ($p = 0.2068$).

In Figure 16 the deformation grids are different in facial proportions. The landmark configuration related to a high digit ratio shows a relatively higher forehead compared to the lower face. Shape changes are also observed in the middle face region of the grids. Eyebrows are developed stronger and located nearer to each other in the left grid than in the middle and the right one. Furthermore the eyes are relatively smaller in grids related to low digit ratio and the distance between the eyes of the left grid is smaller than of the right one. Nose width is smaller in the grid representing a high digit ratio. The lower face of the right grid is narrower compared to the right one and the lips are horizontally lengthened.

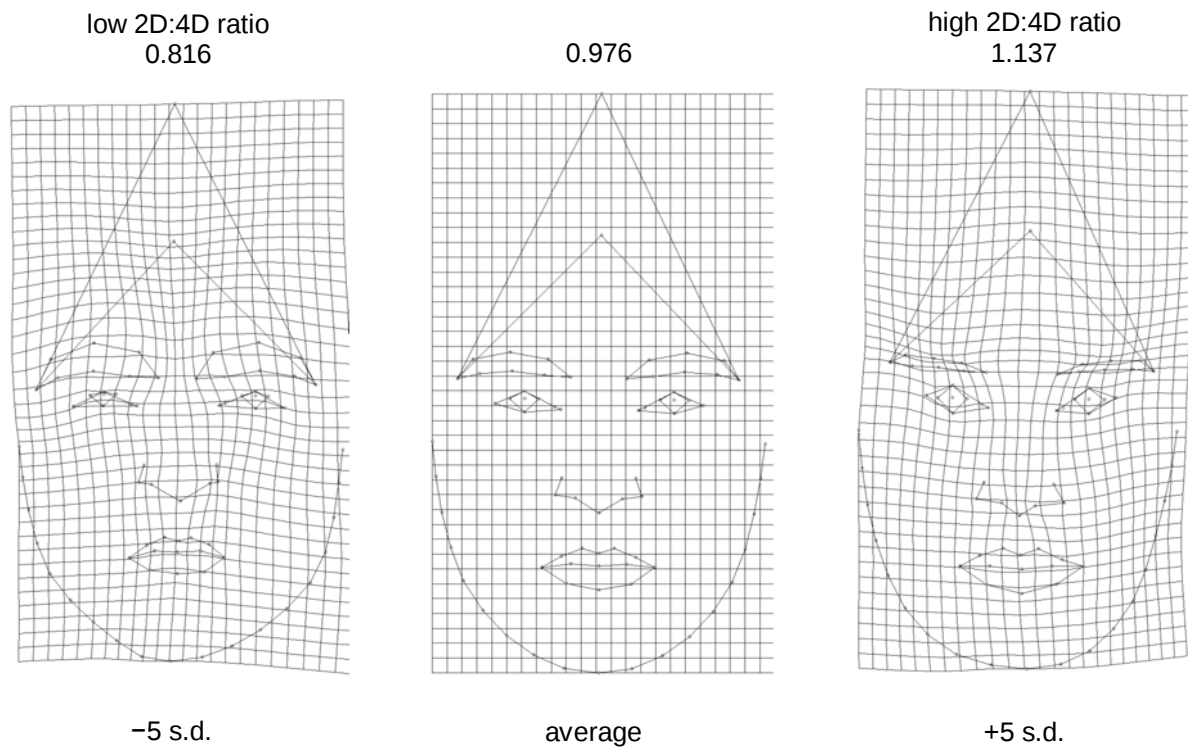


Figure 17. The central grid shows the average configuration for digit ratio of the right hands from right handed males ($n = 22$). On the left grid, shape changes related to low digit ratio are visualized; the right grid shows the face shape characteristic for a high digit ratio (both deformations 5 s.d. enhanced).

The explained variance of shape variation through digit ratio of the right hands from right handed males is 4.5606%. Permutation test failed significance ($p = 0.4685$).

In Figure 17, shape changes in grid configurations related to digit ratio of the right hands are very similar to mean digit ratio of both hands shown before. The deformation grids also show changes in facial proportions, eyes and eyebrows, nose, lower face and lips.

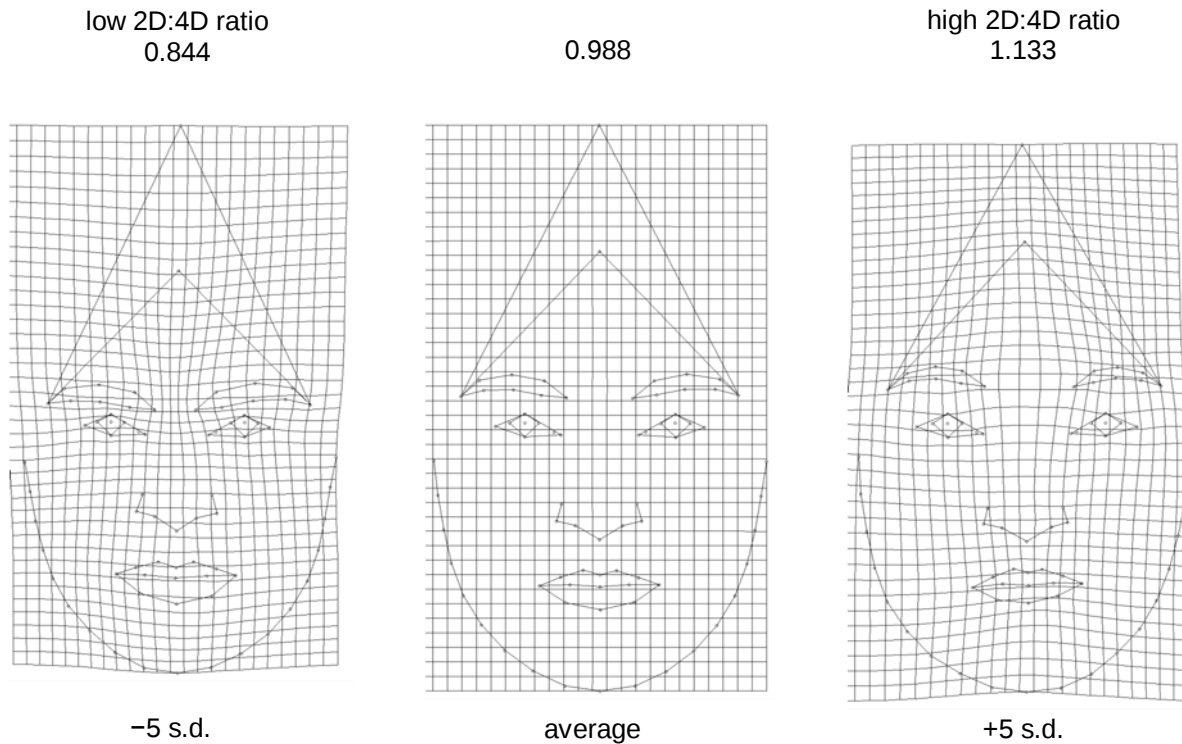


Figure 18. The central grid shows the average configuration for the mean digit ratio of both hands from right handed females ($n = 42$). On the left grid, shape changes related to low digit ratio are visualized; the right grid shows the face shape characteristic for a high digit ratio (both deformations 5 s.d. enhanced).

The explained variance of shape variation through mean digit ratio of both hands from right handed females is 3.8484%. Permutation test failed significance ($p = 0.095$).

In Figure 18 the forehead of the grid related to high digit ratio is broader than the forehead of the left grid. There is no shape change in the size of the eyes, but like in males' grids, the eyebrows are developed stronger in the left grid and the distance between the eyebrows is larger in the right grid compared to the left one. Furthermore, the distances between the eyes on one hand and between eyes and eyebrows on the other hand increase in the grid related to high digit ratio. No shape changes occur in the nose region and shape of the lower face. There is a difference in the lower lip, which is higher in the left grid compared to the right one.

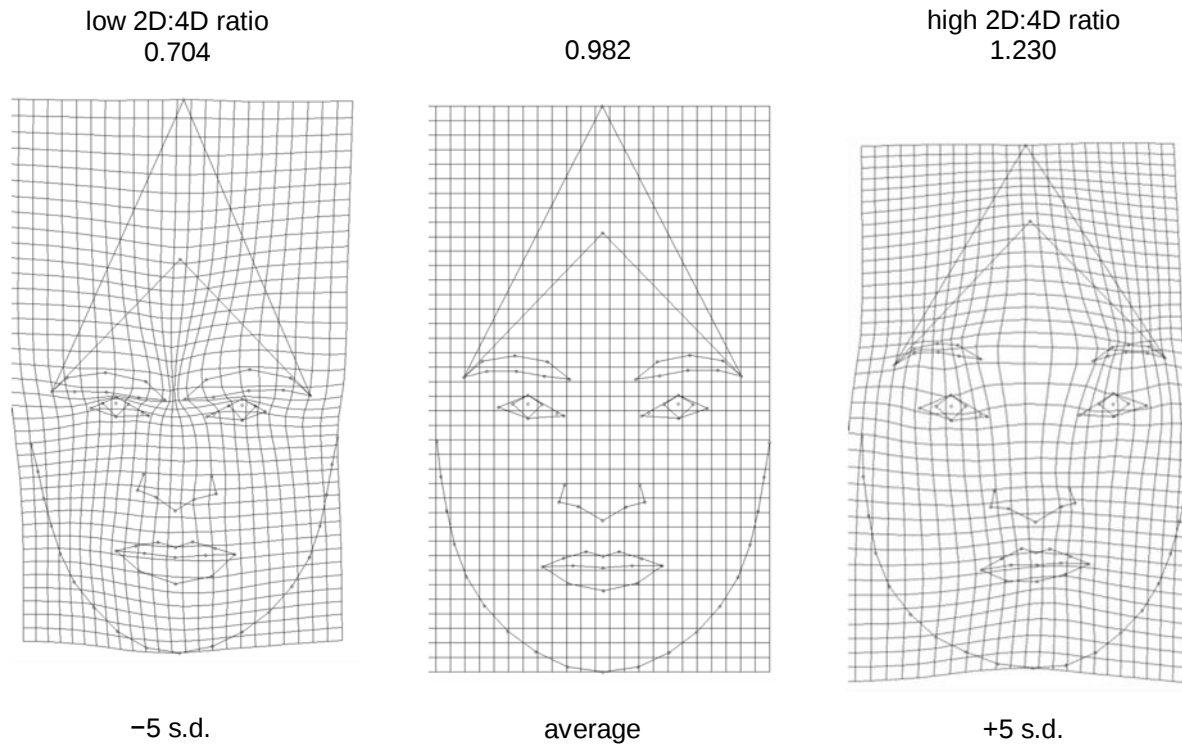


Figure 19 The central grid shows the average configuration for digit ratio of the right hands from right handed females ($n = 42$). On the left grid, shape changes related to low digit ratio are visualized; the right grid shows the face shape characteristic for a high digit ratio (both deformations 5 s.d. enhanced).

The explained variance of shape variation through digit ratio of the right hands from right handed females is 4.7091%. Permutation test was significant ($p = 0.037$).

In Figure 19, shape changes in grid configurations related to digit ratio are similar to these shown before using the mean digit ratio of both hands. The deformation grids also show changes in eyes, eyebrows, and lower lips. The grids using digit ratio of the right hands, show distinct changes in the forehead, which gets higher in the left grid and widens in the right one. Furthermore the lower face is relatively broader and rounder in the grid related to high digit ratio compared to the left one.

3.3 Age and Face Shape

Shape Regression

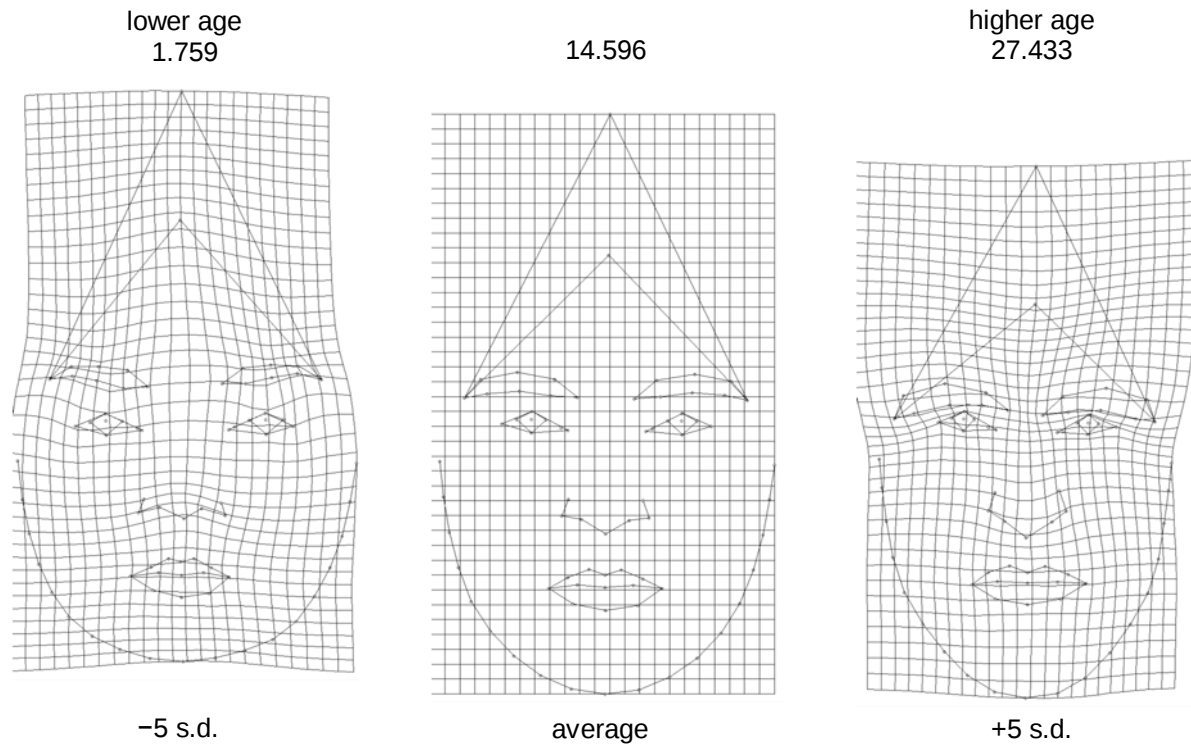


Figure 20. The central grid shows the average configuration for the age of all males ($n = 27$). On the left grid, shape changes related to lower age are visualized; the right grid shows the face shape characteristic of a higher age (both deformations 5 s.d. enhanced).

The explained variance of shape variation through mean age of all males is 8.5401%. Permutation test was significant ($p = 0.0163$).

In Figure 20, the grids show changes in facial proportions. In the left grid the forehead is relatively higher and the lower face smaller and rounder compared to the right grid. Eyes are larger in the grid related to low age while eyebrows are stronger developed in the grid visualizing higher age. Furthermore the distance between the eyes and the distance between the eyebrows is larger in the left grid compared to the right one. The grid area between eyes and eyebrows is also compressed in the grid related to higher age. The shape in the middle area of the face also changes; the nose in the right grid lengthens vertically. The lower face in the right grid, especially the chin, also lengthens vertically, while the lips get larger in horizontal direction.

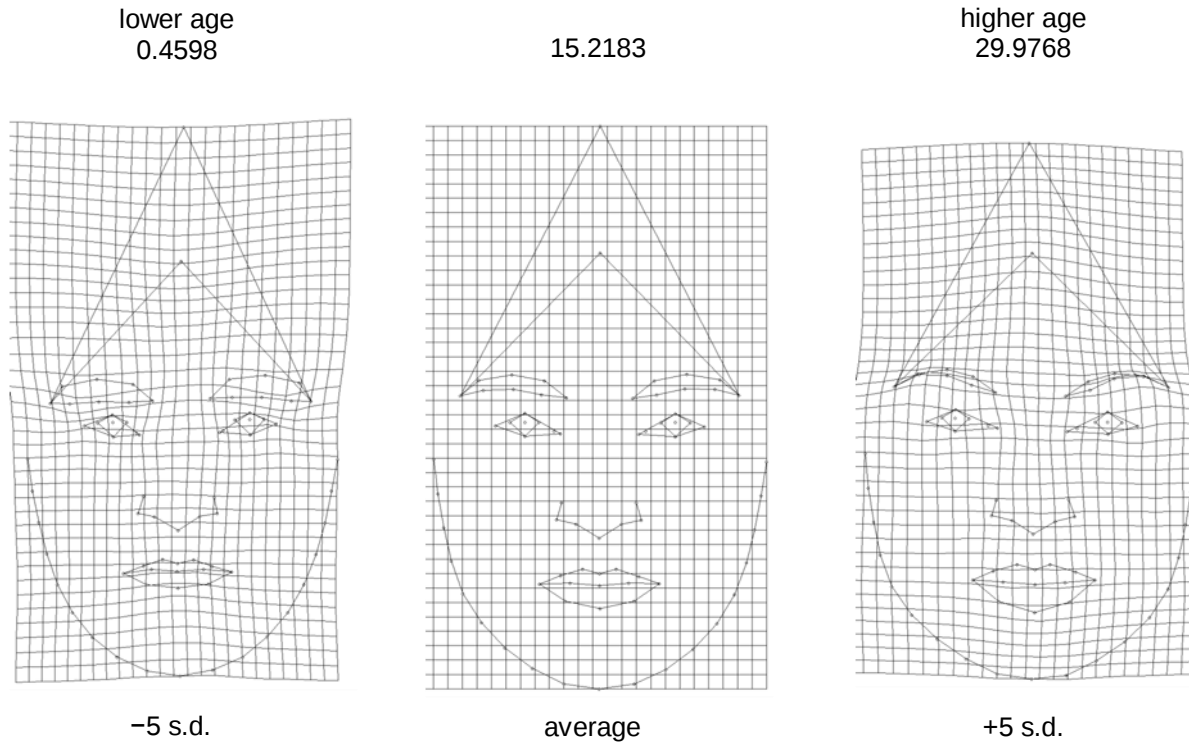


Figure 21. The central grid shows the average configuration for the age from all females ($n = 50$). On the left grid, shape changes related to lower age are visualized; the right grid shows the face shape characteristic for a higher age (both deformations 5 s.d. enhanced).

The explained variance of shape variation through mean age of all females is 2.0842%. Permutation test failed significance ($p = 0.3743$).

In Figure 21, there are no shape changes in eyes and nose between the two grids. Eyebrows are stronger developed in the grid related to low age. The distance between eyes and eyebrows is smaller in the left grid compared to the right one. There is a distinct shape change in the lips which enlarge in the grid related to high age. The lower face is wider and rounder and the chin region seems to be smaller in the right grid.

3.4 Sexual Dimorphism in Face Shape

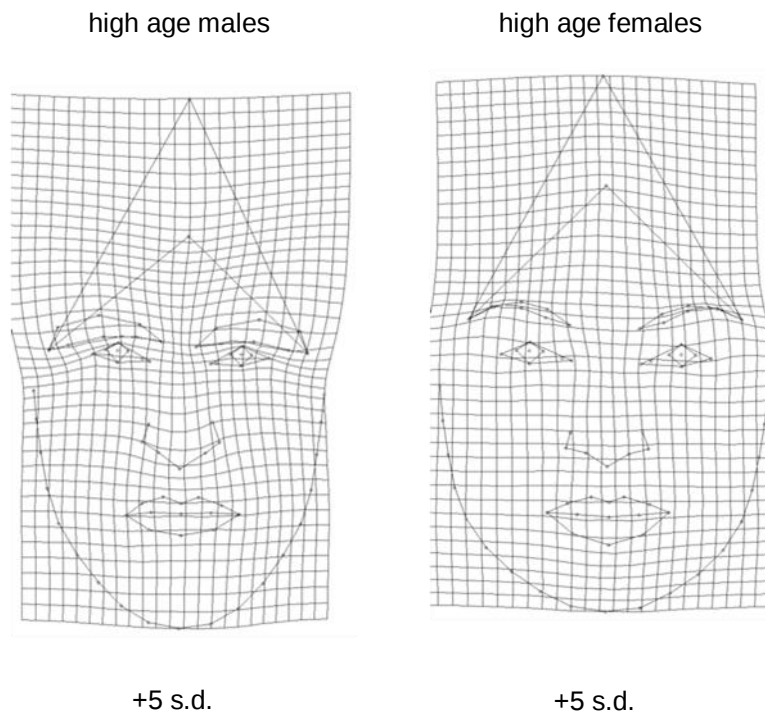


Figure 22 The two grids, representing the regression of age on shape, show differences in shape between the landmark configurations of high aged males and high aged females (both deformations 5 sd enhanced).

In Figure 22, the grids show changes in facial proportions. In the right grid the forehead is relatively larger and the lower face smaller and rounder compared to the left grid. Eyebrows are stronger developed in the grid visualizing males' configuration than in the females' grid. Eyes in the right grid appear to be larger than in the left one. The distance between the eyes and the distance between the eyebrows enlarge in the right grid compared to the left one. Furthermore the distance between eyes and eyebrows is larger in the females' configuration grid than in the males' configuration grid. The nose is longer in the left grid than in the right one. The lower lip enlarges vertically while the chin is compressed vertically in the right grid compared to the left one.

4 Discussion

The regression of digit ratio on face shape with male adolescents was not significant, with female adolescents it was significant only for digit ratio of the right hand. But we found facial patterns related to digit ratio, visualized with deformation grids, with male adolescents, which were similar to findings in traditional literature with male children and adults. Facial patterns in female faces of our sample were not that obvious. They were similar to findings in literature for the upper face, but the lower face of females in our sample was different. With males and females we found a high level of prenatal testosterone, as estimated in the study via 2D:4D digit ratio, lead to more robust faces. Consequently our hypothesis was partially confirmed. In the following discussion we listed some reasons for the results with adolescents and suggested possible strategies for further studies concerning digit ratio and facial shape with adolescents.

4.1 Digit Ratio and Potentially Confounding Variables

Sexual Dimorphism

In finger lengths a significant sexual dimorphism was found. In our study, according to findings in literature (Manning et al., 2010), males' finger lengths were higher than females', which can be assumed due to a sexual dimorphism of size in all parts of the human body.

For our total sample no statistically significant sexual dimorphism in digit ratio was found, but difference in digit ratio of the left hand was nearly significant. Another T-test including only participants aged 12 to 20 years was significant for the left hand. This means that we found no distinct sexual dimorphism in digit ratio in participants aged 12 years or younger, however, in adolescent participants between 12 and 20 years of age a significant sexual dimorphism was shown for the left hand. Our findings are consistent with results from a previous study (Manning et al., 2010), which showed that digit ratio is nearly equal between sexes in children up to an age of twelve and that sexual dimorphism increases from 12 to 20 years of age. These results mean that digit ratios of our sample's participants are normal and comparable to previous studies.

Age

Significant correlations were found for age and the second and fourth fingers of both hands for males. With females, no significant correlations of finger lengths and age were observed. These

results are consistent with previous findings, which showed a stronger, about two years longer lasting, growth of finger lengths in males than in females (Manning et al., 2010). This may be the reason why no significant correlation of finger lengths and age could be found in females.

There was no significant correlation found for age and digit ratio for the total sample, males or females. A comparison of two groups of age, participants older and participants younger than 15 years, did not show any statistically significant differences in digit ratios either. These results lead to the assumption that digit ratio is a relatively stable variable that does not change over the observed age range (10 to 20 years of age).

Body Fat

In contrast to findings in literature (Fink et al., 2003), we observed no significant correlation of body weight, body mass index (BMI), waist circumference, hip circumference, waist to hip ratio (WHR) or body fat and digit ratio. One explanation for these results could be a different age range of our sample. Previous studies were conducted with adults while our study examined adolescents aged 10 to 20 years. All variables mentioned above are related to body fat. It is known that body fat deposition is different with children, adolescents, and adults respectively. Therefore it is possible, that there is a correlation of digit ratio and body mass index, waist and hip circumferences, and waist to hip ratio in adults (Fink et al., 2003) but not in adolescents.

This is relevant for our kind of study because a strong relationship between body fat and digit ratio would have made our shape analysis much more complicated.

4.2 Digit Ratio and Face Shape in Adolescent Males

In contrast to our hypothesis we did not find a significant regression of digit ratio on facial shape for males. However, the patterns of the deformation grids related to high testosterone showed an effect of prenatal testosterone on face shape according to previous findings in literature (Fink et al., 2005; Schaefer et al., 2005; Meindl, 2009): In faces with lower digit ratio eyebrows were developed stronger, the distances between the eyes on one hand and between eyes and eyebrows on the other hand were relatively smaller, eyes were smaller, lips were smaller and the lower face was relatively wider. This joint evidence allows us to assume that we have encountered the same signal in adolescent men. Consequently relationships between digit ratio and facial shape were found for children and adults (Fink et al., 2005; Schaefer et al., 2005; Meindl, 2009) and for

adolescents in our study. These results could be some support for the rejection of the hypothesis from Neave et al. (2003) that the organizational effects of testosterone on facial shape occur in utero but are only activated during puberty.

One possibility for not finding the relationships between digit ratio and face shape to be significant could be our sample size. For shape analysis we only used right handed participants, which were 22 males. In previous literature, for example Fink et al. (2005) used 50 male participants for analysis of face shape and digit ratio in adults. But Meindl (2009) found a significant correlation of digit ratio and face shape in children analyzing only 20 male participants, which leads to the assumption that there were other confounding factors affecting our results. Furthermore the explained variance of face shape through digit ratio for the right hands of right handed males was relatively low in our sample (4.6%) compared to Meindl (2009), who found an explained variance of 12.5%.

Another explanation for not finding that regression to be significant could be a strong relationship between age and face shape for males. This means that there is a lot of variance in face shape (8.5%) explained through age. Our sample's age range (10 to 20 years) is relatively large, so maybe the effect of digit ratio on face shape is too small compared to the effect of age. Splitting the file to compare different groups of age does not seem to be reasonable, because of the very small group size.

Puberty could also be one factor blurring the relationship between digit ratio and face shape. In this period of time, growth spurts were observed between 13 and 15 years for males (Krabbe et al., 1979). This means that in our sample growth velocity is high for a lot of participants, which could overlay the effect of digit ratio on face shape. Furthermore growth rate of individual body segments was found to be different during puberty (Love et al., 1990; Wales, 1998). Therefore it is supposed that there could be different growth rates between parts of the face and digits, which could lead to our results of a non-significant shape regression of digit ratio on face shape in adolescents.

Ethnic differences could also cause a lot of variation in our small sample of right handed males. Although we have excluded many cases with both parents from out of Europe or one parent from out of Europe and the other parent from a country of Central Europe which is not Austria, we left some in with just one parent from out of Europe and the other parent from Austria and some with both parents from different countries of Central Europe because of the time limit of our study. Therefore countries of origin of the participants' parents are very different and could lead to high

variation of digit ratio, which is known to be different for children with various ethnic backgrounds (Manning et al., 2004).

To avoid these influence factors in further studies, it could be helpful to get a larger and more homogenous sample. One possibility would be to take measurements only from right handed males, who have both parents born in Austria. Then the sample could be split into different groups of age to compare effects of digit ratio on face shape without an age related effect. Another way to avoid influence of age would be a statistical correction of age in the sample.

4.3 Digit Ratio and Face Shape in Adolescent Females

Explained variance of face shape through digit ratio with females was similar to males (4.7%). But in contrast to males, a significant regression was found for digit ratio of the right hand and face shape with females. It has to be mentioned that there are nearly twice as many right handed females than males. This larger group size could be responsible for the significant finding.

Our expectation for females was explorative, because there was no significant relationship between digit ratio and face shape found in literature with neither adults nor children (Fink et al., 2005; Meindl, 2009). But we expected similar patterns as in men, namely that a lower digit corresponded to a more robust face shape. This hypothesis could be partially confirmed: Eyebrows are developed stronger and the distance between the eyes is smaller in faces related to low digit ratio. But in the lower face fuller lips were found in faces related to low digit ratio, which is in contrast to findings in literature (Fink et al., 2005).

This findings lead to the assumption that the effect of digit ratio on face shape in females is not strong. Furthermore the correlation of digit ratio and face shape was only significant for the right hand, not for the left hand or the mean digit ratio of both hands, which is one more indication that the signal is not really strong for females. This fact is another hint to the assumption that it is testosterone only which influences the 2D:4D digit ratio (and face shape) and not the testosterone to estrogen ratio.

The possibility that age related effects on face shape overlay the effect of digit ratio on face shape could not be confirmed, because there was no significant regression of age on face shape found with females. Therefore we do not really know how to interpret changes in face shape with digit ratio for females.

4.4 Age and Face Shape

Regression of age on face shape was done for males and females but only statistically significant for males. Pattern changes were observed in both sexes.

With males, low age leads to a higher forehead, a smaller and more rounded lower face, larger eyes and, a larger distance between the eyebrows and a larger distance between eyes and eyebrows. High age is related to stronger developed eyebrows, a vertically lengthened nose, a vertically lengthened chin and horizontally larger lips.

The grid representing low age in females shows stronger developed eyebrows and a smaller distance between eyes and eyebrows. High age leads to larger lips, a broader and more rounded lower face, and a smaller chin region.

The changes of face shape related to age of males agree with previous literature about differences in face shape between children and adults (Enlow et al., 1996). We also found low age correlating with a higher forehead, a smaller lower face, larger eyes and a larger distance between the eyes.

With females, there are some different changes in face shape related to age. We found no age related shape changes in the eye region, the forehead, and in the distance between the eyes.

But there are distinct differences between younger and older females concerning the eyebrows and the lips. Eyebrows are stronger developed in younger faces, which does not have to be a biological effect. Photos of the faces showed that many older girls of our sample shape their eyebrows. Due to previous literature larger lips in older females could be sex hormone markers. A higher estrogen to testosterone ratio in females leads to larger lips because of fat deposition (Thornhill & Gangestad, 1999).

4.5 Sexual Dimorphism in Face Shape

Comparing the male and female grids related to high age, some sexual dimorphic traits were found. According to traditional literature (Enlow et al., 1996) the male grid shows a vertically larger nose and a more prominent chin whereas the forehead in the female grid is higher, and the cheekbones are more prominent. Eyebrows are stronger developed in the grid representing males while lips are horizontally enlarged in the female head, which again seem to be hormone related traits (Thornhill & Gangestad, 1999). These findings confirm our assumption of sexual dimorphic differences in face shape. One important issue is that sexual dimorphic patterns in the human face are different from the effect of the prenatal hormonal environment on facial shape, i.e., prenatal

sex hormone ratios, estimated via 2D:4D digit ratio, and actual chromosomal sex dimorphism operate differently on faces (Fink et al., 2005). Consequently different patterns in male and female faces cannot be explained through the prenatal hormonal environment only.

Conclusion and Future Prospect

Our hypothesis could be confirmed partially. For adolescent men we found distinct patterns in face shape related to digit ratio according to findings in literature, but the regression of digit ratio on face shape was not significant. For females, facial patterns were not that clear and only partially according to former papers. This means that in males aged 10 to 20 years there is already a relationship between the prenatal hormonal environment and robusticity of the face. This fact rejects the hypothesis of Neave et al. (2003), that a relationship between digit ratio and face shape is organized prenatal but activated only during puberty.

For future studies it would be interesting to recruit a larger sample of participants of every age, to compare males and females in every age group especially the two groups of prepubertal and postpubertal participants. Furthermore, measuring the salivary testosterone and estrogen level of the participants would be interesting for a possible comparison of these with prenatal hormone levels, using digit ratio as an indicator.

Considering the negative relationship between 2D:4D digit ratio and perceived masculinity and dominance in traditional literature, our photos and measurements could be used for a rating study, including items like attractiveness, dominance, masculinity and health. This would be interesting to examine potential correlations of digit ratio and perceived characteristics with adolescents and compare them to results of studies concerning adults.

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Appendix

Appendix A. *Table 1.* Correlations of digit ratio and different topics concerning behavior.

Behavior	Digit ratio (2D:4D)				
Sexual Orientation	Males	Hand	Females	Hand	Reference
- Heterosexual	lower 2D:4D	both	no corr.		Lippa, 2003
- Homosexual	higher 2D:4D	both	no corr.		
- Heterosexual	no corr.		higher 2D:4D	right right	Williams, 2000
- Homosexual	no corr.		higher 2D:4D		
Personality Scores					
- SQ	neg. corr.	both	neg. corr.	right	Manning, 2010
- EQ	no corr.		no corr.		
Aggression					
	neg. corr.	left	no corr.		Hoenekopp, 2011
Risk-taking					
	no corr.		neg. corr.	right	Hoenekopp, 2011
	neg. corr.	right	no corr.		Schwerdtfeger, 2010
Cooperation					
- Low digit ratio					Sanchez-Pages, 2010
- Intermediate	more coop.	right	not measured		
- High digit ratio					
Play behavior					
- PSAI	neg. corr.	left	no corr.		Hoenekopp, 2009
Psychopathology					
SDQ (UK)					
- Conduct	neg. corr.	both	no corr.		
- Hyperactivity	neg. corr.	both	no corr.		
- Prosocial beh.	no corr.		pos. corr.	both	
CBLC (Austria)					
- Total score	neg. corr.	left	no corr.		
- Social problems	neg. corr.	left	no corr.		
- Externalizing score	no corr.		neg. corr.	both	Fink, 2007

Appendix B. *Table 2.* Correlations of digit ratio and different disease.

Diseases	Digit ratio (2D:4D)				
Breast cancer	Males	Hand	Females	Hand	Reference
- Age of developing	not measured		neg. corr.	left	Manning, 2001
Autism					
- Autistic children	lower 2D:4D	mean	lower 2D:4D	mean	Manning, 2001
- Healthy children	higher 2D:4D	mean	higher 2D:4D	mean	
- Autistic children	lower 2D:4D	both	lower 2D:4D	both	Naipayok, 2009
- Healthy children	higher 2D:4D	both	higher 2D:4D	both	
CAH					
- Person with CAH	lower 2D:4D	left	lower 2D:4D	right	Brown, 2002
- Healthy person	higher 2D:4D	left	higher 2D:4D	right	
Children with CAH					Ökten, 2002
- comp. to healthy ♂	lower 2D:4D	right	equal 2D:4D	both	
- comp. to healthy ♀	lower 2D:4D	both	lower 2D:4D	both	
Atherosclerosis					
- No fatty streak	higher 2D:4D	right	not measured		Ozdogmus, 2010
- Fatty streak	higher 2D:4D	right	not measured		
- Atheroscler. plaque	lower 2D:4D	right	not measured		

**Fakultät für Lebenswissenschaften
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**Fotografien von menschlichen Gesichtern
zur Erforschung von Veränderungen
im Wachstum**

Veronika Svoboda
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Sehr geehrte Damen und Herren, liebe SchülerInnen und Eltern!

Im Rahmen unserer Diplomarbeiten, unter der Leitung von ao.Univ.Prof. Dr. Katrin Schäfer am Department für Anthropologie der Universität Wien, möchten wir untersuchen, wie sich die Gesichter von Jugendlichen im Wachstum verändern. Neue morphometrische und statistische Methoden erlauben eine ganzheitlichere Betrachtung der Formveränderung des Gesichtes als es bisher möglich war.

Dazu machen wir standardisierte Fotos des Gesichtes von vorne und seitlich. Zusätzlich werden anthropometrische Daten wie Körperhöhe, Körpergewicht und Fingerlängen der TeilnehmerInnen gemessen. Anschließend werden Geschlecht, Geburtsdatum und Informationen wie bisherige Verletzungen des Gesichtes notiert. Die gesamte Datenaufnahme nimmt pro Person nicht länger als eine Viertelstunde in Anspruch. Die erhobenen Daten werden streng vertraulich behandelt.

Im weiteren Verlauf der Studie werden auf die Fotos digital Messpunkte gesetzt und die Koordinatenwerte dieser Punkte statistisch ausgewertet.

**In unserer Diplomarbeit werden die Fotos nur dann gezeigt, wenn Sie ausdrücklich Ihre
Genehmigung dazu erteilen.**

Alle erhobenen Daten werden anonymisiert und streng vertraulich behandelt.

Wenn Sie unsere Diplomarbeit und die Wissenschaft unterstützen wollen, unterschreiben Sie bitte die beiliegende Einverständniserklärung.

Für weitere Erklärungen stehen wir gerne zur Verfügung.

Mit herzlichem Dank im Voraus und freundlichen Grüßen



Karin Patocka & Veronika Svoboda
Wien, im Dezember 2010

Appendix D. Declarations of consent handed out in classes to be signed by the students or their parents, depending on the participants' age.

Einverständniserklärung

Hiermit erkläre ich mich damit einverstanden, dass Karin Patocka und Veronika Svoboda, Department für Anthropologie, Universität Wien, im Zuge ihrer Untersuchungen zum Gesichtswachstum Fotos meines bzw. des Gesichtes meiner Tochter/meines Sohnes machen und die Messwerte unter Wahrung der Anonymität im Rahmen ihrer Diplomarbeit für wissenschaftliche Zwecke verwenden.

Name des Schülers / der Schülerin: _____

Ich erteile darüber hinaus die Genehmigung, diese Fotos in wissenschaftlichen Publikationen im Rahmen der Diplomarbeit zu veröffentlichen: ☐ ja ☐ nein (Zutreffendes bitte ankreuzen).

Der/die Erziehungsberechtigte bzw. bei Volljährigkeit die Schülerin/der Schüler:

Name: _____

Unterschrift: _____

Datum: _____ Ort: _____

Ich möchte bei Erscheinen der Studie per E-Mail verständigt werden:

Meine E-Mailadresse: _____

Von den Studienleiterinnen auszufüllen
Teilnehmer-Nr.:

Appendix E. The questionnaire we used to get information about the date and place of data acquisition, the participants' age, sex, handedness and injuries of fingers and face and also the taking of hormone preparation. Due to ethnic differences in digit ratio we asked for the parents' countries of origin (Datenblatt A for males).

Datenblatt Gesichter A

Teilnehmer-Nr.:

Datum der Datenaufnahme:

Ort:

Geburtsdatum:

Geschlecht: ☐ männlich ☐ weiblich

Körperhöhe (cm):

Taille (cm):

Hüfte (cm):

Körpergewicht (kg):

Körperfett (%):

	2D (Zeigefinger, mm)		4D (Ringfinger, mm)	
Linke Hand				
Rechte Hand				

Händigkeit: ☐ RechtshänderIn ☐ LinkshänderIn

Verletzungen der Finger:

Herkunftsland der Mutter:

Herkunftsland des Vaters:

Geburtskomplikationen, Verletzungen oder Operationen im Gesicht, kieferorthopädische oder kieferchirurgische Maßnahmen (z.B. Zahnsperre):

Frühere oder derzeitige Einnahme von Hormonpräparaten:

DANKE FÜR DEINE MITARBEIT!

Bemerkungen:

Appendix F. The questionnaire we used to get information about the date and place of data acquisition, the participants' age, sex, handedness and injuries of fingers and face and also the taking of hormone preparation. Due to ethnic differences in digit ratio we asked for the parents' countries of origin (Datenblatt B for females).

Datenblatt Gesichter B

Teilnehmer-Nr.:

Datum der Datenaufnahme:

Ort:

Geburtsdatum:

Geschlecht: ☐ männlich ☐ weiblich

Körperhöhe (cm):

Taille (cm):

Hüfte (cm):

Körpergewicht (kg):

Körperfett (%):

	2D (Zeigefinger, mm)		4D (Ringfinger, mm)	
Linke Hand				
Rechte Hand				

Händigkeit: ☐ RechtshänderIn ☐ LinkshänderIn

Verletzungen der Finger:

Herkunftsland der Mutter:

Herkunftsland des Vaters:

Geburtskomplikationen, Verletzungen oder Operationen im Gesicht, kieferorthopädische oder kieferchirurgische Maßnahmen (z.B. Zahnsperre):

Zeitpunkt der 1. Regel (ungefähr):

Frühere oder derzeitige Einnahme von Hormonpräparaten (z.B. Pille):

DANKE FÜR DEINE MITARBEIT!

Bemerkungen:



Sehr geehrte Frau Patocka!
Sehr geehrte Frau Svoboda!

Der Stadtschulrat für Wien erteilt Ihnen die Bewilligung, im Rahmen Ihrer Diplomarbeit mit dem Titel

***„Fotografien von menschlichen Gesichtern
zur Erforschung von Veränderungen im Wachstum“***

eine Fragebogenerhebung bei Schüler/innen vorbehaltlich der Zustimmung der Direktion an den von Ihnen in Ihrem Ansuchen genannten Wiener Schulen

GRg 2 Kleine Sperlgasse 2c
GRg 12 Erlgasse 32-34

durchzuführen.

Für die Untersuchung sind die vorgelegten Unterlagen verbindlich. Bei der Mitarbeit von Lehrer/innen muss der Nachweis der Freiwilligkeit vorliegen.

Alle Untersuchungsergebnisse unterliegen der Anonymität und dürfen nur für die wissenschaftliche Arbeit Verwendung finden.

Mit freundlichen Grüßen
für die Amtsführende Präsidentin:

Mag. Margit Auer eh.
Abteilungsleiterin

Curriculum Vitae

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Computerkenntnisse

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