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Sex Differences in Foetal Biometry, New-born Size and Birth Outcome

Sylvia Kirchengast [1*], Eva Pölzlberger[1#], Erich Hafner[2+], Ingrid Stümpflein[2$] and Beda Hartmann[2@]

[1]University of Vienna, Department of Anthropology, Vienna, Austria
E-mail: [*]<sylvia.kirchengast@univie.ac.at>, [#]<eva-poelzlberger@univie.ac.at>
[2]Danube Hospital, Vienna, Clinic for Gynecology and Obstetrics, Austria
[+]<erich.hafner@weinkav.at>, [$]<ingrid.stümpflein@wiekav.at>,
[@]<beda.hartmann@ wienkav.at>

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ABSTRACT This retrospective study analyses sex differences in foetal biometry from the 1st trimester onwards, and sexual dimorphism in newborn size of 4260 singleton term births taking place at the Viennese Danube hospital between 2005 and 2013. Crown-rump length was determined at the 11th to 12th week, biparietal diameter, fronto-occipital diameter, head circumference, abdominal transverse diameter, abdominal anterior-posterior diameter, abdominal circumference and femur length were determined at the 20th or 21st gestational week and at the 32nd or 33rd week of gestation. Immediately after birth, birthweight, birth length and head circumference were taken, the Apgar scores 1, 5 and 10 minutes after birth were determined. Significant sex differences were found from the first trimester onwards. With exception of femur length, male foetuses exhibited always the significantly larger dimensions. At the time of birth, male newborns were significantly larger and heavier than their female counterparts. Sex had an independent impact on foetal biometry and newborn size.

INTRODUCTION

Sexual dimorphism in size, shape and behaviour is widely found among animal species. Among mammals and particularly among anthropoid primates, sexual size dimorphism is pervasive and males are usually larger than females (Plavcan 2012). This pattern of sexual dimorphism is also typical of human ancestors and recent *Homo sapiens* (Frayer and Wolpoff 1985; Larsen 2003). Across contemporary human populations adult men are approximately 7 percent taller than women of comparable age (Gustafson and Lindenfors 2004, 2009). Sex differences in body size emerge visible for everyone shortly before and after pubertal transition when the pubertal growth spurt takes place (Taylor et al. 1997; Bogin 1999; Kirchengast 2002; Wells 2007). During infancy and childhood, however, girls and boys seem to differ only insignificantly in size. Nevertheless, sex differences in body size and body composition occur much earlier. Studies do indicate sex differences in foetal body size and growth rates for the last fifty years, however the plausible mechanism underlying the sex differences remain elusive (Lubchenco et al. 1963; Tezuka et al. 1998; Lubsky et al. 2006; Lampl et al. 2010; Melamed et al. 2013). There is evidence of sex differences in cell divisions and embryonic metabolism starting from the blastocyst stage (Mittwoch 1993; Bermejo-Alvarez et al. 2008). Furthermore, sex differences in body size are observable as early as the first trimester of pregnancy (Bukowski et al. 2007). In general, male embryos and foetuses show higher growth rates than female ones. Consequently, male and female foetuses differ in body size also during second and third trimester of gestation (Smulian et al. 1995; Guihard-Costa 2006).

In clinical foetal practice the following measurements are used to evaluate intrauterine growth patterns: crown rump length, femur length, biparietal as well as fronto-occipital diameter, anterior-posterior and transversal diameter of the abdomen, head circumference and abdominal circumference. Among healthy foetuses sex differences were found for the head measurements starting with the beginning of the second trimester and for the abdominal dimen-

Address correspondence to:
Dr. Sylvia Kirchengast
University Professor
University of Vienna,
Department of Anthropology,
Althanstrasse 14,
A-1090 Vienna, Austria
Phone: ++431427754712
E-mail: sylvia.kirchengast@univie.ac.at

sions starting with the end of the second trimester (Guihard-Costa 2006). In contrast to Bukowski et al. (2007), no significant sex differences are described for the crown-rump length during the first trimester (Harada et al. 1992; Tezuka et al. 1998) and for the femur length for the whole intrauterine phase (Smulian et al. 1995) by some authors.

Lampl and Jeanty (2003), however, described a significant sex effect in growth velocity patterns of leg length. In detail female foetuses experience earlier growth of the leg bones than their male counterparts (Lampl and Jeanty 2003). Furthermore, sex differences in foetal body composition have been discussed by Farah et al. (2010). Sex differences in body size are also detectable during postnatal phase. At the time of birth, male offspring is heavier and longer and exhibit larger head circumferences (Crawford et al. 1987; Marsal et al. 1996; Pardo et al. 2004; Yankova 2005; Wilkin and Murphy 2006). Additionally, marked differences in body composition are observable between male and female newborns. Newborn girls exhibit a significantly higher amount in relative fat mass in comparison to newborn boys (Shields et al. 2006; Fields et al. 2009). Furthermore newborn girls tend to have slightly higher average skinfold thicknesses indicating a higher amount of subcutaneous fat tissue (Wells 2007). On the other hand, newborn boys exhibited a significantly higher amount in lean body mass in comparison to newborn girls (Shields et al. 2006; Fields et al. 2009). In contrast to soft tissue body composition, newborn boys and girls do not differ in bone mass and bone density (Wells 2007). Newborn boys and girls differ not only in soft tissue body composition (Shields et al. 2006; Wells 2007; Fields et al. 2009) but also in body size. In detail, boys are also more likely to be large for gestational age (LGA) than female newborns (Lampl et al. 2010). Consequently sex dimorphic foetal growth patterns have an important impact on pregnancy outcome and problems occurring during delivery. Macrosomia may lead to prolonged labour and consequently to higher caesarean section rates, on the other hand macrosomia is associated with decreased Apgar scores (Bekedam et al. 2002). To sum up, although newborn boys surpass their female counterparts in size, human males are more vulnerable and show increased morbidity and mortality rates (Stevenson et al. 2000; Elsmen et al. 2004; Finnström 2004; Bekedam et al. 2007; Bertin et al. 2015; Dipietro and Voegtline 2015). The aim of the present study is to analyze sex differences in foetal biometry at the first trimester (11th /12th week), the second trimester (20th/21st week) and the third trimester (32nd/33rd week) as well as at the time of birth.

MATERIAL AND METHODS

Data Set and Study Design

The present retrospective study following a cross-sectional design is based on a data set of 3 prenatal routine check-ups and the outcome of 4260 singleton births which took place at the Danube hospital (SMZ Ost) in Vienna, Austria between 2005 and 2013. The Clinic of Gynaecology and Obstetrics of the Viennese Danube Hospital is one of the largest births clinics in Vienna and altogether 17,430 child births took place at this clinic between 2005 and 2013. Pre- and postnatal care is highly developed in Austria. During the 1970s the so called "Mother-child-Passport" was introduced. This monitoring system includes seven prenatal check-ups starting at the 8th week of gestation and eight postnatal check-ups of the child between birth and the fourth year of life. Not all prenatal check-ups include a sonographic examination. Beside a sonographic entrance examination at the first consultation mainly between 8th and 10th week of gestation, a minimum of 3 sonographic check-ups are performed. One during the first trimester (about 11th/12th gestational week), one at the second trimester (20th/21st gestational week) and one at the third trimester (32nd/33rd gestational week). All check-ups are free of charge and are commonly performed in consulting room of gynaecologists or at the clinic where birth was scheduled to take place. Postnatal examinations took place mainly at the consulting rooms of paediatricians. All data collected at the individual check-ups were documented at the hospital/gynaecologist /paediatrician and in the so-called mother-child passport, which belongs to the mother. A complete mother child passport is rewarded with a financial premium by the government. The introduction of this pre- and postnatal care system reduced neonatal and child mortality dramatically in Austria (Waldhoer et al. 1996).

In order to follow a homogeneous sample as far as possible, the following inclusive criteria were followed:

1. Term births (39^{th} to 40^{th} week of gestation) of healthy primiparae mothers
2. Mothers were of Austrian or Central European origin. This criterion was mainly due to the very small numbers of other ethnic groups
3. All recommended prenatal check-ups of the mother child passport have been performed
4. Delivery of a healthy single infant without congenital malformations
5. No diabetes mellitus before and during pregnancy (no gestational diabetes)
6. No preeclampsia
7. No drug and/or alcohol abuse before and during pregnancy
8. No IFV

4260 births corresponded to these inclusion criterions and were consequently included in the present sample.

Maternal Parameters

Exclusively primiparae women were enrolled in the present study. At the time of birth the mothers aged between 17 and 48 years (x=28.4 ±5.7) were included. At the first consultation family status, family anamnesis and nicotine consumption of the pregnant women were documented. Additionally the following maternal somatometric parameters were collected: Stature height, pre-pregnancy weight (PPW), weight at the end of pregnancy (EPW) and weight gain during pregnancy (PWG). Stature height was measured to the nearest 0.5cm using a standard anthropometer at the first prenatal visit. Pre-pregnancy weight was estimated by means of the retrospective method. Additionally body weight was measured to the nearest 0.1 kg on a balance beam scale at the first prenatal visit (about 8^{th} week of gestation). Weight at the end of pregnancy was measured before birth. Since during the first 13 weeks of gestation an extremely small weight gain of only 1.7 percent was reported in literature (Gueri et al. 1982), in the present study the combination of retrospective method and weight determination at the 8^{th} week of gestation were used. Consequently pre-pregnancy weight was calculated as the mean value of the retrospective estimated weight and the weight at the 8^{th} week of gestation. Pre-pregnancy weight status was determined by using the body mass index (BMI) kg/m^2. To classify maternal weight status the cut-offs published by the WHO (1995) were used. The weight gain during pregnancy was calculated by subtraction of pre-pregnancy weight from body weight at the end of pregnancy. Gestational age was calculated in terms of the number of weeks from the beginning of the last menstrual bleeding to the date of delivery (= duration of amenorrhoea).

Foetal Biometry

In the present study the results of three trans-abdominal sonographic examinations, one at each trimester and the birth outcome are analysed. These sonographic examinations have been carried out routinely as parts of the prenatal mother child passport examinations. All trans-abdominal ultrasound examinations were performed by a limited number of trained specialists using Voluson 730 and Voluson S6 (GE 8) ultrasonography. Inter- and intra-observer reliability tests were performed. According to the American College of Obstetricians and Gynaecologists (2015) the first trimester is defined as the period between conception and 13^{th} week of gestation. The second trimester is defined as the period between 14^{th} and 20^{th} week of gestation and the third trimester is defined as the period between 28^{th} and 42^{nd} week of gestation. The first examination took place during the first trimester at the 11^{th} or 12^{th} week of gestation (x=11.9; SD =0.36), the second examination took place during the second trimester at the 20^{th}/21^{st} gestational week (x=20.9; SD =0.34) and the third examination during the third trimester at the 32^{nd}/33^{rd} week of gestation (x=32.9; SD=0.35). The following routine sonographic measurements, performed according to Hadlock´s criteria (Hadlock et al. 1982a, b, c) were made. At the first scan (11^{th} or 12^{th} gestational week) crown-rump length (CRL) was determined. At the second (20^{th} or 21^{st} gestational week) and the third examination (32^{nd} or 33^{rd} week of gestation) biparietal diameter (BPD), fronto-occipital diameter (FOD), head circumference (HC), abdominal transverse diameter (ATD), abdominal anterior-posterior diameter (APD), abdominal circumference (AC) and femur length (FL). Crown-rump length (CRL) was defined as the distance between the top of the head (crown) to the bottom of the buttocks (rump). Femur length (FL) was measured from the greater trochanter to the lateral condyle. Biparietal diameter (BPD) was defined as the distance from the proximal outer table to the distal outer table of the skull at the level of the thalamus. Fronto-occipital diameter (FOD) follows a line extending from a point just above the root of the nose to the most prominent portion of the occipital bone. Head circumference (HC) is the measurement around the calvarium excluding soft tissues. Transverse and anterior-posterior abdominal diameter were taken at the level of the stomach and the bifurcation of the main portal vein into its right and left branches (Hadlock et al. 1982 a, b, c; Hadlock et al. 1984; Kurmanavicius et al. 1999 a, b; Snijders and Nicolaides 1994; Abdella et al. 2014). Abdominal circumference (AC) was calculated using the following formula AC= π (ATD +APD)/2 (Loughna et al. 2009).

Newborn Parameters

All newborn parameters were taken routinely immediately after birth. The following parameters were directly taken from the newborn: birth weight in grams, birth length in centimetres and head circumference in centimetres. Ponderal index (kg/m^3) of the newborn was calculated (Roje et al. 2004).

A low birth weight was defined as < 2500g, a high birth weight (macrosomia) as >4000g according to the recommendations of the WHO (1980).

The one-minute, five minute and ten minute APGAR scores were determined (Jonnett et al. 1981) for the evaluation of the newborn vital parameters. The Apgar score was introduced in 1952 as a simple and repeatable method to assess the health status of the newborn immediately after birth. Five simple criteria, in detail, skin colour/complexion, pulse rate, reflex irritability, muscle tone and breathing are evaluated using a scale from zero to ten. The Apgar scoring system remains as relevant for the prediction of the neonatal survival today as it was 60 years ago (Casey et al. 2001).

Obstetrical Characteristics

Following obstetric characteristics were documented: the mode of delivery, spontaneous delivery versus caesarean section and the intrauterine position of the infant at the time of delivery (head presentation, pelvic to breech presentation). The most frequent indications for caesarean delivery were foetal distress and dystocia. Caesarean sections on demand were not performed at the Danube hospital.

Statistical Analysis

Statistical analyses were carried out by means of SPSS for Windows (version 22). A Kolmogoroff-Smirnov test was computed in order to test the variables with respect to their normal distribution. No normal distribution was found for Apgar scores. After computing descriptive statistics, student t-tests, Mann-Whitney-u-tests and χ^2 were calculated in order to test sex differences in foetal biometry and newborn size with respect to their statistical significance. Since maternal age differed significantly between male and female offspring a multiple regression analysis was performed to test the impact of sex and maternal age on foetal and newborn biometry independently. Multiple regression was performed for each trimester separately in order to eliminate the effects of repeated measurements in the same individual.

RESULTS

Maternal and Newborn Characteristics

Maternal characteristics are presented in Table 1. A high rate of pre pregnancy overweight and obesity could be observed. According to their BMI, 7 percent of the mothers were classified as underweight, about 65 percent of the mothers were normal weight, 19 percent were classified as overweight and 9 percent of the women as obese. No statistically significant differences between mothers of male and mothers of female offspring were observed for pre-pregnancy weight status, stature height and weight at the end of pregnancy. Mothers of male and mothers of female offspring differed significantly in pregnancy weight gain as well as in chronological age. In detail mothers of male offspring exhibited a significantly higher pregnancy weight gain than mothers of female offspring. Furthermore mothers of female offspring were significantly older than mothers of male offspring.

Sex Differences in Foetal and Newborn Biometry

As presented in Table 2 male and female foetuses differed significantly in all biometric parameters. This was true of crown-rump length at

Table 1: Maternal characteristics according to newborn sex (descriptive statistics)

	Male Mean (SD)/ n (%)	Female Mean (SD)/ n (%)	t/χ^2 Value	Sig p-value
Maternal Age (years)	28.1 (5.3)	28.6 (5.5)	**8.75**	**0.009**
Stature Height (cm)	165.9 (6.2)	166.0 (6.2)	0.98	0.387
Pre pregnancy Weight (kg)	63.9 (13.3)	64.0 (13.5)	0.12	0.826
Weight at the end of Pregnancy (kg)	78.7 (13.9)	78.3 (13.7)	0.32	0.238
Pregnancy Weight Gain	14.8 (5.8)	14.4 (5.5)	**6.74**	**0.015**
Pre pregnancy Body Mass Index (kg/m²)	23.18 (4.51)	23.19 (4.6)	0.14	0.865
Weight Status				
Underweight < 18.50	158 (7.3%)	155 (7.2%)	3.81	0.283
Normal weight 18.50-24.99	1402 (65.4%)	1393 (66.2%)		
Overweight 25.00-29.99	406 (18.9%)	360 (17.0%)		
Obese ≤ 30.00	182 (8.4%)	204 (9.6%)		

Table 2: Sex differences in foetal biometry (student t-tests)

Foetal dimensions	*Male (n=2148)*	*Female (n=2112)*	*Mean differ-ence*	*95% confi-dence inter-val*	*t-value*	*p-value*
	Mean (SD)	*Mean (SD)*				
1. Scan 11/12 Week of Gestation						
Crown-rump length (mm)	61.1 (7.0)	60.3 (6.9)	0.7	0.28 –1.12	**3.28**	**0.01**
2. Scan 20/21 Week of Gestation						
Femur length (mm)	35.7 (1.9)	35.8 (1.9)	-0.1	-0.29 - -0.02	**-2.25**	**0.025**
Fronto-occipital diameter (mm)	67.6 (2.9)	66.5 (2.8)	1.1	0.87 –1.21	**12.06**	**0.001**
Biparietal diameter (mm)	53.4 (2.5)	52.4 (2.3)	1.0	0.89 –1.17	**14.22**	**0.001**
Head circumference (mm)	190.1 (7.2)	186.8 (6.8)	3.3	2.82 –3.65	**15.40**	**0.001**
Abdominal transversal diameter (mm)	49.4 (3.2)	48.8 (3.1)	0.6	0.35 –0.73	**5.62**	**0.001**
Abdominal anterior-posterior diameter (mm)	51.8 (3.7)	50.9 (3.8)	0.8	0.60 – 1.05	**7.24**	**0.001**
Abdominal circumference (mm)	158.9 (8.8)	156.7 (8.9)	2.2	1.65 – 2.70	**8.15**	**0.001**
3. Scan 32/33 Week of Gestation						
Femur length (mm)	63.2 (2.7)	63.5 (2.6)	-0.3	-0.43 --0.11	**-3.33**	**0.01**
Fronto-occipital diameter (mm)	108.6 (4.7)	107.3 (4.7)	1.3	1.03 – 1.59	**9.13**	**0.001**
Biparietal diameter (mm)	87.6 (3.4)	86.5 (3.4)	1.1	0.89 – 1.30	**10.55**	**0.001**
Head circumference(mm)	308.5 (10.9)	304.7 (10.8)	3.8	3.10 – 4.41	**11.25**	**0.001**
Abdominal transversal diameter (mm)	85.9 (5.3)	85.6 (5.1)	0.4	0.07 – 0.69	**2.38**	**0.018**
Abdominal anterior-posterior diameter (mm)	88.8 (5.7)	88.2 (5.4)	0.6	0.29 – 0.96	**3.77**	**0.001**
Abdominal circumference (mm)	274.6 (13.6)	273.1 (13.3)	1.6	0.76 – 2.38	**3.81**	**0.001**
Difference between 2 and 3 Scan						
Femur length (mm)	27.5 (2.7)	27.7 (2.7)	-0.2	-0.31 – 0.02	-1.73	0.083
Fronto-occipital diameter (mm)	40.9 (4.9)	40.7 (4.9)	0.3	-0.04 – 0.55	1.69	0.092
Biparietal diameter (mm)	34.1 (3.3)	34.1 (3.3)	0.0	-0.14 – 0.26	0.62	0.537
Head circumference (mm)	118.4 (10.9)	117.9 (11.1)	0.5	-0.16 – 1.16	1.49	0.135
Abdominal transversal diameter (mm)	36.6 (5.4)	36.7 (5.4)	-0.2	-0.49 – 0.16	-1.01	0.314
Abdominal anterior-posterior diameter(mm)	37.1 (6.0)	37.3 (6.1)	-0.2	-0.56 – 0.17	-1.06	0.290
Abdominal circumference (mm)	115.7 (13.5)	116.3 (14.1)	-0.6	-1.41 -0.24	-1.37	0.169

the $11^{th}/12^{th}$ gestational week but also of femur length, head dimensions and abdominal dimensions at the $20^{th}/21^{st}$ and $32^{nd}/33^{rd}$ week of gestation. With the exception of femur length at the $20^{th}/21^{st}$ as well as at the $32^{nd}/33^{rd}$ gestational week male foetuses surpassed their female counterpart significantly. Concerning biometric increase between $20^{th}/21^{st}$ and $32^{nd}/33^{rd}$ gestational week no significant sex differences were observed. No significant sex differences were found for the increase of foetal biometry between second and third scan. Although statistically insignificant, female foetuses exhibited a higher increase in abdominal dimensions than their male counterparts.

At birth, male newborns were significantly longer, heavier and exhibited a significantly higher head circumference than newborn girls. Highly significant (p =0.001) sex differences were found for newborn weight status. Macrosomia was significantly more prevalent among male newborns, while significantly more female newborns were classified as low weight. Nevertheless the rate of low birth weight was quite low in both sexes (1.4% and 2.0%) (Table 3).

As presented in Table 4, the significant impact of sex independent of maternal age on all foetal absolute biometric parameters as well as on newborn somatometrics was shown by the results of regression analyses. Male sex was associated with larger foetal dimensions with the exception of femur length at the second as well as at the third scan. Femur length was positively associated with the female sex. Male sex was also positively associated with newborn dimensions. Maternal age, in contrast has an independent significant positive impact on crown-rump length at the $11^{th}/12^{th}$ gestational weeks and on abdominal anterior-posterior diameter as well as on abdominal circumference at the $20^{th}/21^{st}$ gestational week only. No significant impact of maternal age on newborn size was documented.

Sex Differences in Birth Mode and Child Presentation

Regarding Apgar score it turned out, that girls had significantly higher mean Apgar score after 1 minute and after 5 minutes than boys (see Table 3). The Apgar score after 10 minutes did not differ significantly between the two sexes. Furthermore no statistically significant sex differences were found for birth modus and child presentation. In both sexes the rate of caesarean sections was about 16 percent. Regarding child presentation it could be shown that head presentation was found among the vast majority (about 95%) of the newborns. This was true of both sexes (see Table 5).

DISCUSSION

Sexual size dimorphism in humans emerge visible mainly during and after pubertal transition (Bogin 1999), nevertheless sex differences in size are also reported for newborns (Vattern and Skjaerven 2004). The earliest known English report of sexual dimorphism in foetal and neonatal outcomes was given by Joseph Clarke in 1786. (Clarke 1786). Clarke analysed the data of more than 20,000 deliveries which took place at the Lying-In Hospital in Dublin between 1757 and 1784. According to Clarke, male newborns were larger and heavier than their female counterparts, on the other hand he observed greater mortality of males than females (Clarke 1786). These findings have been reported consistently in scientific literature up to now (Di Renzo et al. 2007; Engel et al. 2008). During the last 20 years sex differences in size are also described for intrauterine phase (Smulian et al. 1995; Schwärzler et al. 2004; Lubusky et al. 2006; Lampl et al. 2010; Melamed et al. 2013). There is a consensus that male foetuses surpass their female counterparts

Table 3: Sex differences in newborn size and vital parameters (student t-tests/ Mann Whitney u-tests /Chi-squares)

Newborn somatometrics	*Male (n=2148)* Mean	*(SD)*	*Female (n=2112)* Mean	*(SD)*	*95% confidence interval*	*Mean difference*	*t-value u-value/χ^2*	*p-value*
Birth Weight (g)	3457.2	(444.1)	3313.7	(410.2)	117.67–169.05	143.5	10.93	**0.001**
Birth Length (cm)	51.1	(2.1)	50.4	(1.9)	0.57–0.81	0.7	11.28	**0.001**
Ponderal Index (kg/m³)	2.59	(0.24)	2.59	(0.27)	-0.01–0.02	0.001	0.28	0.777
Head Circumference (cm)	34.5	(1. 4)	33.9	(1.3)	0.44–0.59	0.6	12.67	**0.001**
Newborn Weight Status								
SGA <2500g	30	(1.4%)	42	(2.0%)			71.65	**0.001**
2500-4000g	1863	(86.8%)	1969	(93.2%)				
LGA >4000g	255	(11.9%)	101	(4.8%)				
Apgar								
Apgar 1 minute	9.1	(1.2)	9.2	(1.1)		0.1	**-2.72**	**0.006**
Apgar 5 minute	9.7	(0.8)	9.8	(0.7)		0.1	**-3.97**	**0.001**
Apgar 10 minute	9.9	(0.6)	9.9	(0.5)		0.1	-1.78	0.076

Table 4: Multiple regression analysis for each trimester separately: Impact of sex and maternal age on foetal biometry and newborn size

	Multi-ple R	*Regre-ssion coeffi-*	*Sig.*	*95% confi-dence interval*	*Regre-ssion coeffi-*	*Sig.*	*95% confi-dence interval* .
1. Scan							
Crown-rump length	0.05	-0.72	**0.001**	-1.14- -0.30	0 .04	**0.050**	0.00 - 0.08
2. Scan							
Biparietal diameter	0.21	-1.03	**0.001**	-1.17- -0.89	0 .01	0 .643	-0 .01 -0.02
Fronto-occipital diameter	0.18	-1.03	**0.001**	-1.20- -0.87	-0 .01	0 .206	-0 .03 -0.01
Head circumference	0.23	-3.23	**0.001**	-3.64- -2.82	-0 .01	0 .556	-0 .05 -0.03
Abdominal transverse diameter	0.09	-0.54	**0.001**	-0.73- -0.36	0 .01	0 .590	-0 .01 -0.02
Abdominal anterior-posterior diameter	0.11	-0.85	**0.001**	-1.07- -0.63	0 .04	**0 .001**	0 .02 -0.06
Abdominal circumference	0.13	-2.22	**0.001**	-2.74- -1.69	0 .07	**0 .005**	0 .02 -0.12
Femur length	0.04	0.13	**0.024**	0.02 - 0.24	-0 .01	0 .817	-0 .01 -0.01
3. Scan							
Biparietal diameter	0.16	-1.11	**0.001**	-1.31- -0.90	0 .02	0 .089	-0 .01 -0.04
Fronto-occipital diameter	0.14	-1.32	**0.001**	-1.60- -1.04	0 .02	0 .080	-0 .03 -0.05
Head circumference	0.17	-3.80	**0.001**	-4.426- -3.15	0 .08	0 .014	0 .02 -0.14
Abdominal transverse diameter	0.04	-0.39	**0.015**	-0.70- -0.07	0 .01	0 .339	-0 .02 -0.04
Abdominal anterior-posterior diameter	0.06	-0.64	**0.001**	-0.97- -0.31	0 .03	0 .101	-0 .01 -0.06
Abdominal circumference	0.06	-1.61	**0.001**	-2.41- -0.79	0 .06	0 .109	-0 .01 -0.14
Femur length	0.05	0.26	**0.001**	0.10 - 0.42	0 .01	0 .064	-0 .01 -0.03
Birth Size							
Birth weight	0.17	-143.28	**0.001**	-169.1--117.6	-0 .14	0 .911	-2 .51 -2.24
Birth length	0.17	-0.69	**0.001**	-0.82- -0.58	0 .01	0 .128	-0 .01 -0.02
Head circumference	0.19	-0.52	**0.001**	-0.60- -0.44	0 .01	0 .058	0 .01 -0.02

Table 5: Sex differences in birth mode and child presentation

	Male (n=2148) *n (%)*	*Female (n=2112)* *n (%)*	χ^2	*Sig.*
Child Presentation				
Head presentation	2024 (94.3%)	1989 (94.2%)	1.61	0.448
Pelvic to breech presentation	124 (5.7%)	123 (5.8%)		
Birth Modus				
Vaginal delivery	1795 (83.6%)	1786 (84.6%)	1.78	0.534
Caesarean section	353 (16.4%)	326 (15.4%)		

in head as well as abdominal dimensions from the second trimester onwards (Smulian et al. 1995; Tezuka et al. 1998). Concerning the first trimester however there is still no consensus regarding sex differences in size. On the one hand, Harada et al. (1992) and Tezuka et al. (1998) found no marked sex differences in crown –rump length during the first trimester and femur length throughout intrauterine period. Bukowski et al. (2007) in contrast, reported a significant sex difference in crown-rump length during the first trimester of gestation.

In the present study sex differences in foetal biometry were analysed at the first, second and third trimester as well as at birth. Starting with the evaluation of crown-rump length during the first trimester, in particular at the 11th or 12th week of gestation, it could be shown that male foetuses were significantly longer than their female counterparts. These findings are in accordance with those of Bukowski et al. (2007) who reported significant sex differences in crown-rump length between eight to twelve weeks of gestation. On the other hand the results of the present study are in contrast to those of Harada et al. (1992) and Tezuka et al. (1998) who did not find significant sex differences in crown-rump length for the first gestational trimester. Furthermore in the present study significant sex differences for head and abdominal dimensions during the second and third trimester could be proved. Sex had a significant independent impact on head and abdominal dimensions. As to be expected males foetuses exhibited always significantly higher dimensions. These findings correspond with the results of several previous studies, which described this kind of sexual size dimorphism for the second and third trimester of gestation (Davis et al. 1993; Smulian 1995; Tezuka et al. 1998; Guihard-Costa 2006). Additionally significant sex differences were found for femur length during second and third trimester. This finding however is in contrast to that of some previous studies, which reported no significant sex differences in femur length during intrauterine phase (Davis et al. 1993; Smulian et al. 1995; Guihard-Costa and Droulle 1990). In the present study female foetuses exhibited significantly longer femurs than their male counterparts at the second as well as at the third trimester. Therefore the observed sex differences of femur length were in contrast to the patterns of sexual dimorphism found for head and abdominal dimensions. This finding corresponds with the results of Lampl and Jeanty (2003) who described a faster leg growth among female foetuses. A larger femur length among female foetuses in comparison to male ones was also described by Pang et al. (2003). Furthermore, Waszak and Cieslik (2003) also described an earlier development among female foetuses. In general the present study yielded a marked sexual dimorphism in foetal biometry. The reason for this sexual dimorphism of foetal biometry however, remains still unclear (Melamed et al. 2013). Effects of foetal sex on genetic and environmental regulators of foetal growth are discussed. It is assumed that these sex dependent regulators such as androgens, may have different effects on different foetal body parts (de Zegher et al. 1998; Hughes et al. 2002). At the time of birth - as to be expected - newborn boys were significantly longer, heavier, more robust and exhibited a significantly higher head circumference than newborn girls. This finding is in accordance with numerous previous studies all indicating that newborn boys are generally larger than their female counterparts (Clarke 1786; Crawford et al. 1987; Marsal et al. 1996; Rodriguez et al. 2004; Yankova 2005). Sexual size dimorphism among newborns is not only found among humans but also among non-human primates (Smith and Leigh 1998; Joffe et al.

2005; Geary et al. 2003). In the present sample the mean birth weight of term males exceeded that of term females by 143.5g. This sex difference in birth weight is minimally higher than that of US term newborns. US term male newborns were 131 gg heavier than their female counterparts (National Centre of Health Statistics 2001). Additionally newborn males of the present sample were 0.7 cm longer than newborn girls and their head circumference exceeded that of girls by 0.6 cm. Similar results were documented for US newborns (National Centre of Health Statistics 2001). Additionally the rate of macrosomia (>4000g) was significantly higher among newborn boys. Concerning birth outcome however newborn boys exhibited significantly lower Apgar scores. This was true of the Apgar score after one minute, after five minutes and after ten minutes. In contrast no significant sex differences in the caesarean section rate were documented. On the one hand the results of the present study indicate a marked sexual dimorphism in body size from the first trimester onwards, on the other hand male newborns exhibit lower APGAR scores. Boys grow faster and have a higher metabolic rate than girls during gestation, however when oxygen is limited they might deplete available resources more rapidly (Bennet et al. 2007). The increased male vulnerability against environmental stress factors was formulated in so called “male disadvantage hypothesis” by Richard Naeye more than 40 years ago (Naeye et al. 1971). This hypothesis tried to explain the increased risk of perinatal morbidity and morbidity in boys in comparison with girls. A sex-biased sensitivity against environmental stress factors is described for humans (Stevenson et al. 2000; Elsmen et al. 2004; Finnstörm 2004; Thomas et al. 2006; Hussein et al. 2007; Drevenstedt et al. 2008) but also for several animal species (Kalmbach et al. 2005). Clifton (2010) suggested that sex specific adaptation of the placenta may be central not only to the differences in intrauterine growth but also in morbidity and mortality. According to this hypothesis male and female placentas response in a sex specific manner to the same maternal environment resulting in sex differences in growth and vulnerability.

CONCLUSION

It can be concluded that sexual size dimorphism is detectable from the first intrauterine trimester onwards and continue to postnatal period. Newborn males are larger however they showed lower Apgar scores indicating that the males may be the larger sex however also the more vulnerable one.

LIMITATIONS OF THE STUDY

Without any doubt the main limitation of the present study is the cross-sectional and retrospective design. Consequently it was not possible to analyse foetal growth patterns but only differences in cross-sectional size.

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