OBSTETRICS

# Does pregnancy and/or shifting positions create more room in a woman's pelvis?

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**OBJECTIVE:** The purpose of this study was to assess the impact of different positions on pelvic diameters by comparing pregnant and nonpregnant women who assumed a dorsal supine and kneeling squat position.

**STUDY DESIGN:** In this cohort study from a tertiary referral center in Germany, we enrolled 50 pregnant women and 50 nonpregnant women. Pelvic measurements were obtained with obstetric magnetic resonance imaging pelvimetry with the use of a 1.5-T scanner. We compared measurements of the depth (anteroposterior (AP) and width (transverse diameters) of the pelvis between the 2 positions.

**RESULTS:** The most striking finding was a significant 0.9-1.9 cm increase (7-15%) in the average transverse diameters in the kneeling squat position in both pregnant and nonpregnant groups. The average bispinous diameter in the pregnant group increased from 12.6 cm $\pm$ 0.65 cm in the supine dorsal to 14.5 cm $\pm$ 0.64 cm ($P < .0001$) in the kneeling squat; in the nonpregnant group the increase was from 12 cm $\pm$ 0.76 cm to 13.9 cm $\pm$ 1.04 cm ($P < .0001$). The average bituberous diameter in the pregnant group increased from 13.6 cm $\pm$ 0.93 cm in the supine dorsal to 14.5 cm $\pm$ 0.83 cm ($P < .0001$) in the kneeling squat position; in the nonpregnant women the increase was from 12.6 cm $\pm$ 0.92 cm to 13.5 cm $\pm$ 0.88 cm ($P < .0001$).

**CONCLUSION:** A kneeling squat position significantly increases the bony transverse and anteroposterior dimension in the mid pelvic plane and the pelvic outlet. Because this indicates that pelvic diameters change when women change positions, the potential for facilitation of delivery of the fetal head suggests further research that will compare maternal delivery positions is warranted.

**Key words:** birth, magnetic resonance imaging (MRI), maternal position, pelvimetry, pregnancy

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This study had its origins in our experience of vaginal breech birth over the last 10 years in a tertiary hospital in Frankfurt, Germany, where women were encouraged to give birth in an upright position. We noticed that babies who were born in this position encountered fewer mechanical problems during birth and had fewer admissions to the neonatal intensive care unit. We hypothesized from these observations that a nonsupine position may result in increased pelvic diameters that facilitate the birth of the baby.

Over the centuries, obstetricians and particularly midwives have encouraged women to adopt various positions during childbirth to increase pelvic dimensions and thereby facilitate birth.[1,2] Such position changes have been advocated for challenging births that included breech vaginal birth.[3-5] These considerations are relevant, given a recent revival of interest in vaginal breech birth.[6] Published guidelines for breech birth have favored the semilithotomy dorsal position, whereas some individual centers favor more upright positions.[6-8] Published evidence to support either approach is very limited.

Magnetic resonance imaging (MRI) has become the method of choice if obstetric pelvimetry is needed.[9] It is done conventionally with the woman on her back. There are few studies that have reported pelvic measurements in women who adopt other positions.[10] This is the first study of MRI pelvimetry in pregnant women to compare the conventional supine position with a different position.

Our primary objective was to compare anteroposterior and transverse pelvic dimensions between women who assumed the kneeling squat and supine dorsal positions. The secondary objective was to compare these changes between pregnant and nonpregnant subjects.

## Methods

Pregnant women who requested a vaginal breech birth were included if they were >18 years old with a singleton fetus presenting in breech position and who had stated their preference for a

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FIGURE 1
**Kneeling squat position**

A 1.5-T magnetic resonance scanner (Magnetom Espree, Siemens, Erlangen, Germany).

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FIGURE 2
**Pelvic anteroposterior measurements according to the protocol used**

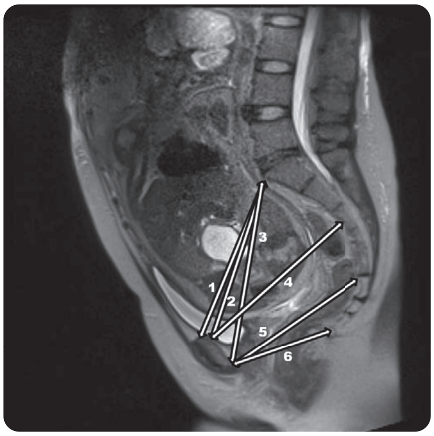


Table 1 provides the exact definition of the anatomic landmarks and the distance. *1,* Anatomic conjugate; *2,* obstetric conjugate; *3,* diagonal conjugate; *4,* anteroposterior diameter of mid plane; *5,* anteroposterior diameter of lower mid plane; *6,* anteroposterior outlet.

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vaginal breech birth. After these women were seen and counseled in our breech clinic, the MRI was done on average at 37+3 weeks of gestation (range, 35+2—39+2 weeks of gestation). The same number of nonpregnant women were recruited with the use of flyers at the university site and were included if they were >18 years old with no clinical evidence of pregnancy. We excluded all women with metal prostheses or who had any contraindication for having a vaginal breech birth (eg, known fetal malformation and/or intrauterine growth retardation). All women provided written informed consent.

The 70-cm inner bore diameter of the MRI limited women to adopt a kneeling squat position (Figure 1) that represented the most upright position possible. We compared these pelvimetry measurements with those obtained in the conventional supine dorsal position.

The examinations were performed with a 1.5-T MR scanner (Magnetom Espree; Siemens, Erlangen, Germany). The examination started with each woman in the supine dorsal position undergoing a specified imaging protocol (Appendix). Women were then asked to assume a kneeling squat position (Figure 1), and measurements were compared by adherence to the same imaging protocol as that used in the supine dorsal position. The duration of the examination did not exceed 10 minutes. All pelvic bony dimensions were measured on an Advantage Workstation (GE Healthcare, London, UK) by 2 readers using standard digital measurement techniques. The readers then agreed on the measurement.

The anteroposterior pelvic measurements were from the related anatomic planes (Table 1; Figure 2). Three different measurements were used for the pelvic inlet (anatomic conjugate, obstetric conjugate, and diagonal conjugate). Two measurements were used for the mid pelvic cavity (anteroposterior diameter of mid plane [APDM]) to the second sacral vertebra and an anteroposterior diameter of mid plane to the sacral tip (lower APDM) and 1 for the pelvic outlet (anteroposterior outlet).

The transverse pelvic measurements corresponded to the related anatomic planes (Table 2; Figures 3 and 4). These

TABLE 1
**Pelvic anteroposterior diameters used in obstetric magnetic resonance imaging pelvimetry[a]**

| Name | Other names | Distance between different anatomic planes |
|---|---|---|
| Anatomic conjugate | Pelvic inlet, true conjugate | Distance from the upper tip of pubic symphysis to the sacral promontory |
| Obstetric conjugate | Obstetric diagonal | Distance from the narrowest bony points formed by the sacral promontory and the inner pubic bone |
| Diagonal conjugate | Historically used as a digital measurement to judge what the inaccessible pelvic inlet would be | Distance from the lower border of pubic symphysis to sacral promontory |
| Anteroposterior diameter of mid plane | Mid cavity, widest part of the pelvis | The shortest distance from the mid point of the third sacral bone to the inner border of pubic symphysis |
| Anteroposterior diameter of lower mid plane | Some groups consider it to be part of the outlet (called in that case anteroposterior outlet) | Distance from the sacrococcygeal joint to the lower tip of the symphysis pubis |
| Anteroposterior outlet | Pelvic outlet, sagittal outlet | Distance from the tip of the coccygeus to the lower tip of the symphysis pubis |

[a] See Figure 2 for further information.

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**TABLE 2**
**Pelvic transverse diameters used in obstetric magnetic resonance imaging pelvimetry**

| Name | Other names | Distance between different anatomic planes |
|---|---|---|
| Bispinous diameter[a] | Bispinous outlet | Distance between the the ischial spines behind the hipjoint |
| Bituberous diameter[b] | Ischial tuberosity distance | Distance between the posterior part of the tuber ischiadici (sit bones) of the ischial bone: forming the base of a triangle with anterior angle |
| Anterior angle[b] | | The angle at the apex of the anterior triangle with the boundaries:<br>• Apex: the lamina fibrocartilaginea interpubica of the pupic bone<br>• Base: the bituberous diameter<br>• Sides: formed by the pubic rami and ischial tuberosities |

[a] See Figure 3 for further information; [b] See Figure 4 for further information.

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were the bispinous and the bituberous diameters and an anterior angle.

In addition to these measurements, the lumbosacral line contour was assessed and categorized as 1 of classical C form, straight form, or a form in between.[11] In the pregnant group maternal and neonatal outcome data were collected and analyzed (Table 3).

The data were assessed for the normal distribution assumption by the Skewness Kurtosis test in which normally distributed, continuous variables were presented as means with their corresponding standard deviation (SD). The Student *t* test was used to compare paired measurements in the 2 groups (pregnant and nonpregnant) and the 2 different positions. Wilcoxon's signed rank sum test was used for the comparison of measurements not normally distributed. Further the paired Student *t* test was used to compare the changes in pregnant and nonpregnant women, which were defined as the differences between the respective measurements in supine dorsal and kneeling squat position in each woman. All tests were 2-sided and used a significance level of .05. All results are presented as means and standard deviations or medians with corresponding 25−75% ranges. Statistical analysis was performed using SPSS software (20/Stata/IC 13.0; StataCorp LP, College Station, TX).

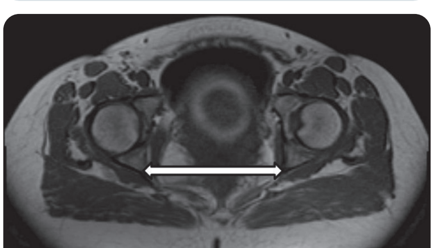
## RESULTS

Data from 50 pregnant women and 50 nonpregnant women that were collected between May 1, 2011, and Aug. 31, 2012, were analyzed for the anteroposterior measurements. Fewer data were available for the transverse plane because of difficulties visualizing the appropriate plane (Tables 4 and 5) MRI pelvimetry proved feasible in all cases, both in the supine dorsal and in the kneeling squat positions (Figure 1). It should be noted that the volunteer nonpregnant women were on average younger (5.5 years; $P < .0001$) and heavier (12.4 kg; $P < .0001$) than the pregnant group (with the use of the first recorded weight during pregnancy, which usually reflects the prepregnancy weight).

### Anteroposterior measurements

In both the pregnant and nonpregnant groups, all 3 anteroposterior inlet measurements decreased (range, 0.1−0.4 cm) when the women changed from supine to the kneeling squat position (Table 4). The obstetric conjugate in the pregnant group in the kneeling squat position measured 12.2 ± 0.83 cm and in the supine dorsal position measured 12.62 ± 0.8 cm ($P < .0001$). In the nonpregnant group, the obstetric conjugate was 12.42 ± 1.06 cm in the kneeling squat position and was 12.6 ± 1.13 cm ($P < .0001$) in the supine dorsal position. The anatomic conjugate was 12.96 ± 0.79 cm in the kneeling squat position and 13.11 ± 0.84 cm in the

**FIGURE 3**
**Pelvic transverse diameter-bispinous diameter**



The *arrow* indicates the landmarks of our meassurements as specified in Table 2.

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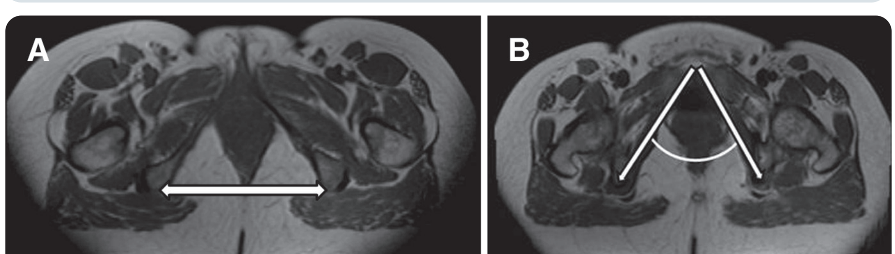
**FIGURE 4**
**Pelvic transverse diameter-bituberous and anterior angle**




**A,** Diameter-bituberous and **B,** anterior. The *arrow* indicates the landmarks of our meassurements as specified in Table 2.

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TABLE 3
**Maternal and neonatal characteristic of the pregnant group**

| Variable | Measure | SD |
|---|---|---|
| Maternal age at delivery, y[a] | 32.04 (20.55—40.94) | 4.255 |
| Parity | | |
| Primiparous | 48 | |
| Multiparous | 2 | |
| Gestational age at delivery, wk[a] | 39.8 (37.3—42.0) | 0.979 |
| Mode of delivery, n (%) | | |
| Spontaneous vaginal delivery | 16 (32) | |
| Planned cesarean delivery | 11 (22) | |
| Cesarean delivery during labor | 18 (36) | |
| Emergency cesarean delivery | 2 (4) | |
| Not known | 3 (6) | |
| Obstetric conjugate, n (%) | | |
| <12 cm | 9 (18) | |
| ≥12 cm | 41 (82) | |
| Birth position, n (%) | | |
| Kneeling squat | 16 (32) | |
| Left lateral dorsal (operating theater) | 31 (62) | |
| Unknown | 3 (6) | |
| Pelvic shape | | |
| C curve | 42 (84) | |
| Straight | 6 (12) | |
| In between | 2 (4) | |
| Apgar score[b] | | |
| 5-Minute | 9.78 (7.0—10.0) | 0.593 |
| 10-Minute | 9.96 (9.0—10.0) | 0.206 |
| Arterial cord pH (median)[b] | 7.256 (7.00—7.37) | 0.0713 |
| Fetal weight, g[a] | 3297.3 (2155.0—4340.0) | 428.03 |
| Percentile, n (%) | | |
| <10 | 5 (10.6) | |
| 10-90 | 41 (87.2) | |
| >90 | 1 (2.1) | |

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supine dorsal position in the pregnant group ($P = .0016$). In the nonpregnant group, the anatomic conjugate was 13.17 ± 1.02 cm in the kneeling squat position and 13.27 ± 1.05 cm in the supine dorsal position ($P = .0069$). Furthermore, the diagonal conjugate was 14.05 ± 0.91 cm in the kneeling squat position and 14.31 ± 0.99 cm in the supine dorsal position in the pregnant group ($P < .0001$). In the nonpregnant group, the diagonal conjugate was 14.17 ± 1.19 cm in the kneeling squat position and 14.28 ± 1.23 cm in the supine dorsal position ($P < .0001$).

The anteroposterior mid pelvic and the anteroposterior pelvic outlet measurements in contrast increased (range, 0.2—0.49 cm) in the kneeling squat position in both pregnant and nonpregnant groups. In the pregnant group, the APDM measured 13.65 ± 0.77 cm in the kneeling squat position and 13.45 ± 0.77 cm in the supine dorsal position ($P < .0001$); the lower APDM was 11.88 ± 0.94 cm in the kneeling squat position and 11.51 ± 0.98 cm in the supine dorsal position ($P < .0001$). In the nonpregnant group, the APDM was 13.42 ± 0.92 cm in the kneeling squat position vs 13.17 ± 0.88 cm ($P < .0001$) in the supine dorsal position, and the lower APDM was 11.61 ± 0.79 cm vs 11.41 ± 0.79 cm in the kneeling squat position vs the supine dorsal position, respectively ($P < .0001$).

Finally, the anteroposterior pelvic outlet in the pregnant group was 9.1 ± 1 cm in the kneeling squat position and 8.61 ± 1.03 cm in the supine dorsal position ($P < .0001$). In the nonpregnant group, the anteroposterior pelvic outlet was 8.87 ± 0.83 cm and 8.59 ± 0.85 cm in the kneeling squat and the supine dorsal positions, respectively ($P < .0001$).

The APDM was increased (by 0.39 cm) in the pregnant group when compared with the nonpregnant group in the kneeling squat position ($P = .0247$). All the other anteroposterior measurements did not differ between the pregnant and nonpregnant groups.

When we compared the change in the pelvic diameters from the kneeling squat position to the supine dorsal position, changes in the obstetric and diagonal conjugate diameters were significantly greater in the pregnant group than in the nonpregnant group (obstetric conjugate change, 0.4 cm in pregnant vs 0.18 cm in nonpregnant; $P < .0001$; diagonal conjugate change, 0.27 cm in pregnant vs 0.11 cm in nonpregnant; $P = .0045$, respectively). All the other changes were not significantly different between the pregnant group and the nonpregnant groups (Figure 5).

## Transverse measurements

The MRI transverse pelvimetry measurements of the pregnant group and the nonpregnant group are presented in Table 5. In the pregnant group, the

**TABLE 3**
**Maternal and neonatal characteristic of the pregnant group** *(continued)*

| Variable | Measure | SD |
|---|---|---|
| Head circumference, cm[a] | 35.55 (32.0—38.0) | 1.190 |
| Fetal length, cm[a] | 51.74 (46.00—58.00) | 2.489 |

Although those pregnant women who were included in the magnetic resonance imaging study had requested a vaginal delivery, because of the unit's policy, a vaginal breech delivery was not recommended if the obstetric conjugate was <12 cm. In the unit, a vaginal breech delivery is offered regardless of type of breech (frank, incomplete, complete; only for footling breech diagnosed in labor will a cesarean delivery be performed). In the group with the obstetric conjugate of ≥12 cm, 39 datasets were completed; 16 women (39.02%) had a vaginal breech birth; all of which were in the upright position. Of these 16 deliveries, 12 deliveries were in frank breech; 3 deliveries were in incomplete breech, and 1 baby was in a complete breech position. Five women (12.19%) had a planned cesarean delivery either because the requirements for offering a vaginal breech delivery were not fulfilled or because of the mothers' wishes. Two emergency cesarean deliveries (4.87%) were performed during labor because of abnormal electronic fetal monitoring. In 16 women (39.02%), a cesarean delivery was done because of no progress in the first or second stage, fetal distress, or a combination of these. Two women (4.87%) were lost to follow-up evaluation.

[a] Data are given as mean (range); [b] Data are given as median (range).

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bispinous diameter in the kneeling squat increased (range, 0.9—1.8 cm) when women changed from the supine dorsal position from 12.6 ± 0.65 cm to 14.5 ± 0.64 cm ($P < .0001$). In the nonpregnant group, these results are similar, with the bispinous diameter increasing from 12 ± 0.76 cm in the supine dorsal position to 13.9 ± 1.04 cm in the kneeling squat position ($P < .0001$). The bituberous diameter in the pregnant group also increased from 13.6 ± 0.93 cm in the supine dorsal position to 14.5 ± 0.83 cm ($P < .0001$) in the kneeling squat position. The bituberous diameter in the nonpregnant group increased from 12.6 ± 0.92 cm in the supine dorsal position to 13.5 ± 0.88 cm ($P < .0001$) in the kneeling squat position. The anterior angle increased from 74 ± 5 degrees in the supine dorsal position to 77 ± 4 degrees ($P < .0001$) in the kneeling squat position.

In the nonpregnant group, the anterior angle significantly increased by 5 degrees from 70 ± 5 degrees in the supine dorsal position to 75 ± 4 degrees ($P < .0001$) in the kneeling squat position.

We found that the pregnant women in our cohort had wider transverse pelvic measurements compared with nonpregnant women in both the supine dorsal and the kneeling squat positions (bispinous supine dorsal pregnant group 12.46 cm vs nonpregnant 12.02 cm; $P = .0105$; kneeling squat pregnant group 14.36 cm vs nonpregnant 13.84 cm; $P = .0195$; bituberous supine dorsal pregnant

**TABLE 4**
**Magnetic resonance imaging pelvimetry anteroposterior planes in supine dorsal and kneeling squat positions in the pregnant and nonpregnant groups**

| | Magnetic resonance imaging pelvimetry | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Supine dorsal, cm | | | | Kneeling squat, cm | | | | | | |
| Group | Mean | SD | Minimum | Maximum | Mean | SD | Minimum | Maximum | Difference[a] | n | *P* value |
| Pregnant | | | | | | | | | | | |
| Anatomic conjugate | 13.11 | 0.84 | 11.13 | 14.63 | 12.96 | 0.79 | 10.98 | 14.63 | −0.14 | 49 | .0016 |
| Obstetric conjugate | 12.62 | 0.80 | 10.68 | 14.07 | 12.22 | 0.83 | 10.27 | 13.96 | −0.4 | 49 | < .0001 |
| Diagonal conjugate | 14.31 | 0.99 | 11.93 | 16.23 | 14.05 | 0.91 | 12.11 | 16.06 | −0.27 | 47 | < .0001 |
| Anteroposterior diameter of mid plane | 13.45 | 0.77 | 11.36 | 15.99 | 13.65 | 0.77 | 11.78 | 15.31 | +0.2 | 45 | < .0001 |
| Lower anteroposterior diameter of mid plane | 11.51 | 0.98 | 9.76 | 14.31 | 11.88 | 0.94 | 9.61 | 14.72 | +0.37 | 42 | < .0001 |
| Anteroposterior outlet | 8.61 | 1.03 | 6.96 | 11.25 | 9.10 | 1.00 | 7.10 | 11.85 | +0.49 | 42 | < .0001 |
| Nonpregnant group | | | | | | | | | | | |
| Anatomic conjugate | 13.27 | 1.05 | 11.16 | 15.79 | 13.17 | 1.02 | 11.35 | 15.59 | −0.1 | 50 | .0069 |
| Obstetric conjugate | 12.60 | 1.13 | 10.72 | 15.32 | 12.42 | 1.06 | 10.74 | 15.04 | −0.19 | 50 | < .0001 |
| Diagonal conjugate | 14.28 | 1.23 | 12.23 | 16.99 | 14.17 | 1.19 | 11.98 | 16.98 | −0.11 | 50 | < .0001 |
| Anteroposterior diameter of mid plane | 13.17 | 0.88 | 11.41 | 15.29 | 13.42 | 0.92 | 11.78 | 15.58 | +0.25 | 49 | < .0001 |
| Lower anteroposterior diameter of mid plane | 11.41 | 0.79 | 9.63 | 13.78 | 11.61 | 0.79 | 10.16 | 13.89 | +0.20 | 48 | < .0001 |
| Anteroposterior outlet | 8.59 | 0.85 | 6.56 | 10.74 | 8.87 | 0.83 | 6.91 | 11.32 | +0.28 | 49 | < .0001 |

[a] Difference in the measurements between the 2 positions.

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**TABLE 5**
**Magnetic resonance imaging pelvimetry transverse planes in the pregnant and nonpregnant groups**

| | Magnetic resonance imaging pelvimetry | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Supine dorsal | | | | Kneeling squat | | | | | | |
| Group | Mean | SD | Minimum | Maximum | Mean | SD | Minimum | Maximum | Differance[a] | n[b] | *P* value |
| Pregnant | | | | | | | | | | | |
| Bispinous diameter, cm | 12.6 | 0.65 | 10.94 | 13.91 | 14.5 | 0.64 | 11.25 | 16.30 | +1.8 | 33 | < .0001 |
| Bituberous diameter, cm | 13.6 | 0.93 | 10.16 | 15.53 | 14.5 | 0.83 | 11.78 | 16.20 | +0.9 | 28 | < .0001 |
| Anterior angle, degrees | 74 | 5 | 60 | 84 | 77 | 4 | 63 | 85 | +3 | 35 | < .0001 |
| Nonpregnant | | | | | | | | | | | |
| Bispinous diameter, cm | 12.0 | 0.76 | 10.16 | 15.22 | 13.9 | 1.04 | 11.25 | 16.47 | +1.9 | 39 | < .0001 |
| Bituberous diameter, cm | 12.6 | 0.92 | 10.79 | 14.84 | 13.5 | 0.88 | 11.88 | 15.63 | +0.9 | 28 | < .0001 |
| Anterior angle, degrees | 70 | 5 | 59 | 81 | 75 | 4 | 68 | 82 | +5 | 44 | < .0001 |

[a] Difference in the measurements between the 2 positions; [b] Numbers are lower than for anteroposterior diameters because the appropriate anatomic plane could not be confidently visualized.

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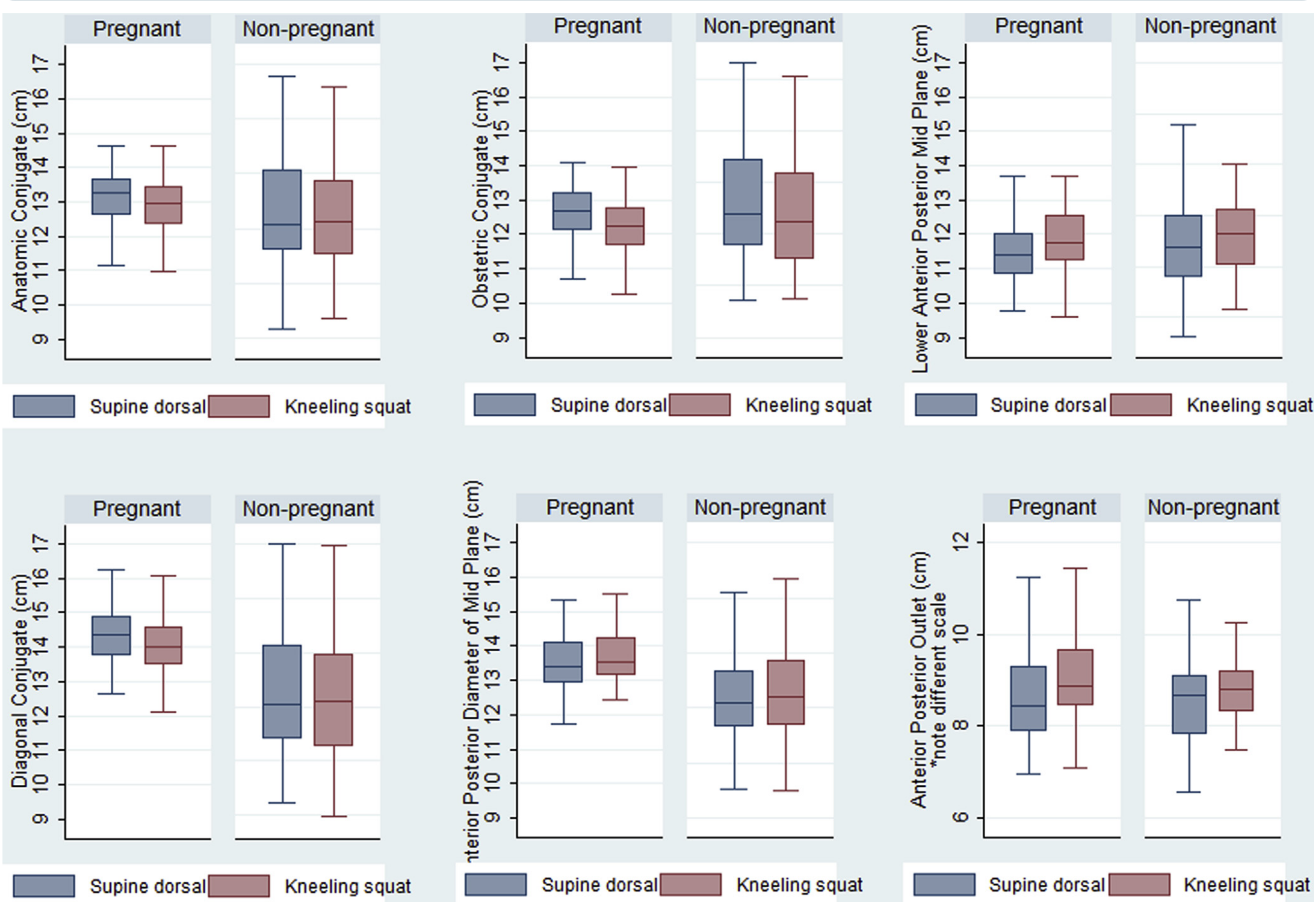
**FIGURE 5**
**Different anteroposterior pelvic dimensions**




The supine dorsal and kneeling squat position in pregnant and nonpregnant women.

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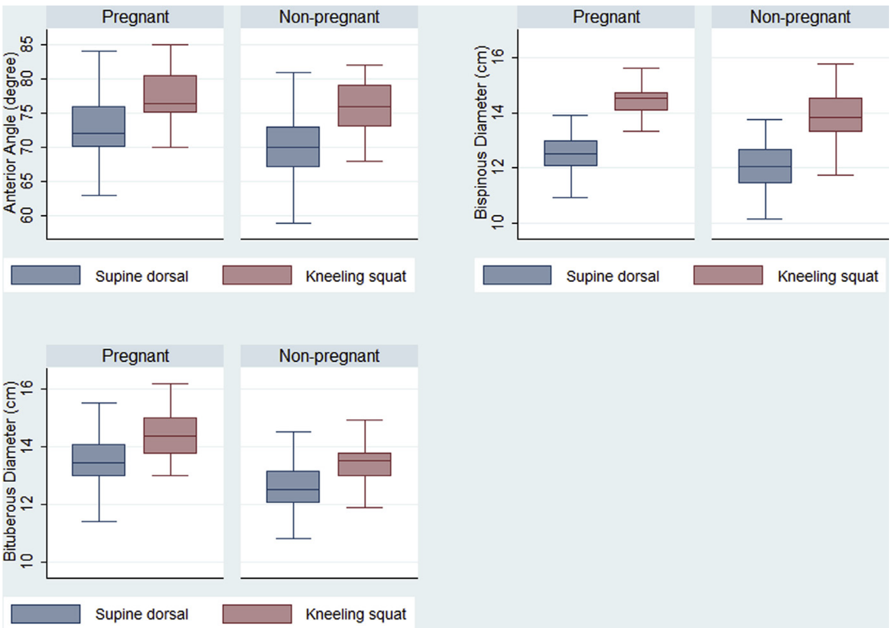
FIGURE 6
**Different transverse pelvic dimensions**




The supine dorsal and kneeling squat position in pregnant and nonpregnant women.

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group 13.41 cm vs 12.6 cm nonpregnant group, $P = .0005$; kneeling squat pregnant group 14.37 cm vs nonpregnant group 13.57 cm; $P = .0008$). Changes in the transverse measurements between the supine dorsal and the kneeling squat positions were similar in pregnant and nonpregnant women (Figure 6). The pelvic shape showed no significant difference between the nonpregnant and the pregnant group ($P = .025$); the majority in both groups had a C form. Maternal and neonatal characteristics are presented in Table 3.

## Comment

This is the first study to compare MRI pelvimetry of pregnant and nonpregnant women in different positions. The results show a striking and significant increase in the transverse diameters of the mid pelvis and the pelvic outlet (0.9−1.9 cm) when women change from the supine dorsal position to a kneeling squat position; this increase is larger than the increase in the corresponding anteroposterior measurements. The increase is even more pronounced in pregnant women.

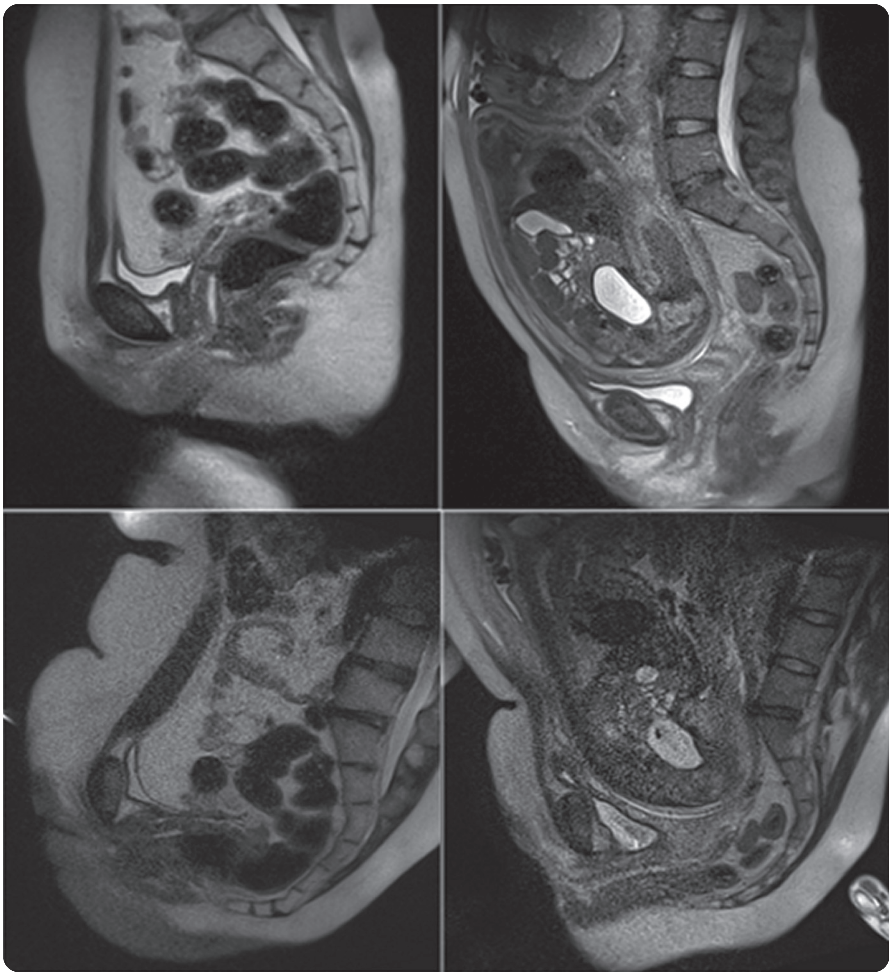
The results from this study also show how narrow the range of measurements is for the female human pelvis. This is reflected in the small standard deviations and further in the highly significant probability values for only small differences in measurements taken in different positions. These tight ranges exist, despite the variation in weight and age between the pregnant and nonpregnant groups.

These results are consistent with a similar smaller study of nonpregnant women by Michel et al[10] that showed, for the first time with MRI, that changes in a woman's position led to changes in pelvic diameters. They reported a significant increase in the anteroposterior outlet and bispinous diameter with women on their hands and knees. As in our work, Michel et al described a smaller obstetric conjugate in a hands and knees position compared with the supine dorsal position.[10] Together, these studies support an anatomic rationale for the age-old observation that change to a more upright position for birthing appears advantageous for the woman who is pushing in the second stage of labor. Maternity care providers often have emphasized the value of women changing to a more upright position at the time of the baby's birth.[2,12] Until now, there has not been direct measurable evidence in pregnant women to support the value and importance of such a position change.[13,14]

The increase in transverse diameters, shown in our data, appears to compensate for a decrease in anteroposterior inlet diameters, possibly facilitating rotation of the presenting part of the baby. These changes are more pronounced in pregnant women compared with nonpregnant women, although some studies have shown no such changes. Huerta-Enochian et al[15] have observed a relative stability of pelvic measurements through the course of pregnancy and postnatal period. Gupta et al[16] reported no statistically significant change in x-ray pelvimetry in the sitting and squatting position on the fifth or sixth postnatal day. Our results suggest a dynamic component in the female pelvis that may be more pronounced during parturition to facilitate birth.

Given that the kneeling squat position resembles the McRoberts position, the aforementioned results suggest a different explanation for the efficacy of the McRoberts maneuver in the management of shoulder dystocia. This maneuver has been observed to flatten the sacral promontory and thereby thought to increase the anteroposterior of the inlet.[2,17] Our results and images show that the sacral promontory is flattened in the kneeling squat position; however, this is not accompanied by an increase in the inlet anteroposterior diameter; in fact, there is a decrease. The flattening of the sacral promontory facilitates a more direct line of entry for the baby to enter the pelvic canal (Figure 7). More important, our results show that the McRoberts maneuver increases the critical transverse diameters (bispinous and bituberous); the movement to achieve these changes leads to the shoulders being able to rotate into the more spacious pelvic mid cavity. In addition, this MRI study confirms the teaching that the increase in diameter relies more on the

FIGURE 7
**Visible general pelvic changes because of change in maternal position**



*Top left*, nonpregnant supine dorsal; *top right*, pregnant supine dorsal; *bottom left*, nonpregnant modified kneeling squat; *bottom right*, pregnant modified kneeling squat.

*Reitter. Obstetric MR pelvimetry changes according to position. Am J Obstet Gynecol 2014.*

hyperflexion of the maternal hips without any abduction.[2]

Despite the statistically significant changes in the anteroposterior diameters, it is reasonable to ask whether these are clinically relevant, given the small changes (≤0.49 cm). Small dimensional differences in pelvimetry have always been influential in decisions about the clinical adequacy of the pelvis.[18] Symphysiotomy, which results in small increases in pelvic diameters (0.5 cm), can allow difficult shoulders or a trapped after-coming head to deliver.[19,20]

Our MRI study does not justify the routine clinical use of pelvimetry. However, it provides an anatomic explanation for some long-held obstetric and midwifery opinions regarding the advantage of an upright position during birth for both cephalic and breech presentations.

In the case of breech vaginal birth for which there are potential concerns about the adequacy of the pelvis for the passage of the after-coming head, these changes in pelvic dimensions should encourage practitioners to consider advising women to change their position because, even the small increases in diameter, could be critical in facilitating a safe birth.

Smellie and Veit (covered in Drife[5]), Loevset,[4] and Bracht[3] were among those who pioneered maneuvers to assist the vaginal breech, all of which required that the mother be on her back. Bracht[3] was the first obstetrician who recognized the possible negative effect of gravity that is produced when the mother is in the dorsal position. Reevaluating their diagrams and theoretic implications, Louwen et al[8] adapted the more upright birth positions for vaginal breech. Some preliminary data suggest that, when women are in various upright positions (eg, sitting on her heels, kneeling, or leaning forward on hands and knees), the birth is subjected to fewer manual maneuvers (classic, Bickenbach, Bracht, Loevset, Mauriceau-Smellie-Veit) that have the potential to increase both neonatal and maternal morbidity.[8] The clinical utility of pelvimetry (however done) has not been proved.[21] In the past, pelvic measurements that were obtained with x-ray, computed tomography, and more lately MRI have been used to determine pelvic adequacy for women who are considering a vaginal breech birth.[22] Van Loon et al[23] showed no clear value from such an approach in predicting the success of an attempted vaginal breech birth. MRI pelvimetry, as used in our study, provides us with a better understanding of how the human pelvis changes in critical dimensions when the woman assumes different positions and how these changes could be significant for the facilitation of any birth.

Recent literature and guidelines in Europe, Israel, Canada, and Australia now promote the vaginal delivery of breech babies as an acceptable alternative to cesarean delivery if certain requirements are fulfilled.[24-27] All these current considerations of vaginal breech birth assume that the mother will give birth on her back. Little consideration is given to the potential for other positions to facilitate the birth at the critical time of expulsion. Our study provides a rationale for rethinking this time-honored position of birth in favor of an upright position. The same rethinking should apply to cephalic births.

Our study has some potential limitations. We used a kneeling squat position because with the limitation of the MRI, the subjects could not adopt a more upright squat (Figure 1), which may or may not open the pelvis further. Our study does not exclude the possibility that simply by hyperflexing the knees onto the chest in a dorsal supine position might achieve the same changes. Our numbers are not large enough to rule out any effect of height, weight, or ethnicity of the women on the pelvic measurements. A further limitation is that the control supine position is strictly not an obstetric birthing position, which indicates that the key valuable change is hyperflexion of the maternal knees onto the abdomen. The strength of our study is the inclusion of both pregnant and nonpregnant women. A further strength is the ability to measure precisely the pelvic dimensions with the most accurate imaging technology.

In conclusion changing from the supine dorsal to the kneeling squat position significantly increases the bony anteroposterior and transverse dimensions in the mid pelvic plane and the pelvic outlet, thus providing the anatomic rationale for easier descent of the baby in that part of the pelvis. The small decrease in the anteroposterior inlet is accompanied by a relatively larger increase in the mid plane transverse dimension. This change is even more profound and statistically significant in the pregnant group. The significance of this study lies in its unique contribution to our understanding of the dynamic physiologic condition of the birth canal. Further comprehensive research that will compare maternal position relevant to vaginal birth (breech and cephalic) is warranted. ■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## APPENDIX

The obstetric pelvimetry was performed with a 1.5-T magnetic resonance scanner (Magnetom Espree; Siemens, Erlangen, Germany). The examination started with each woman in the supine dorsal position undergoing a specified imaging protocol. A flexible body phase array coil (Siemens) was positioned at the woman's pelvis. After the coil position had been checked with a gradient-echo localizer sequence, FLASH (fast low angle shot) 2-D gradient-echo sequence (echo time/repetition time = 74/4.8; 5-mm section thickness; 256 × 256 matrix) were acquired at transverse and anteroposterior section orientations with the use of a 400-mm field of view. Supplementary anteroposterior T2-weighted HASTE (half-Fourier acquisition single-shot turbo spin-echo) sequences (echo time/repetition time = 900/85; 3-mm section thickness) were acquired.