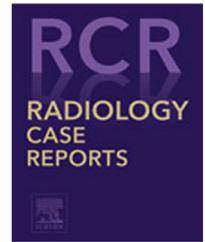


Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.elsevier.com/locate/radcr

Case report

Changes in pelvic alignment in a woman before and after childbirth, using three-dimensional pelvic models based on magnetic resonance imaging: A longitudinal observation case report

Asuka Sakamoto, PhD^{a,*}, Goro Watanabe, PhD^b, Tsuyoshi Morito, Ms^c,
Kimio Katayama, RT^d, Hajime Kumagai, MD^d, Kazuyoshi Gamada, PhD^e

^a Faculty of rehabilitation sciences, Nishikyusyu university, 4490-9 Osaki, Kanzaki-machi, Kanzaki-shi, Saga-ken, 842-8585, Japan

^b Department of physical therapy, Kawahara medical science institute, 3-6 Hanazono-cho, Matsuyama-shi, Ehime-ken, 790-0005, Japan

^c School of sport sciences, Waseda university, 579-15 Sangashima, Tokorozawa-shi, Saitama-ken, 359-1192, Japan

^d Department of radiology, Hiroshima Minato Clinic, 12-46 Ujinanishi, Minami-ku, Hiroshima-shi, Hiroshima-ken, 734-0014, Japan

^e Research division, GLAB Co., Ltd., 889-1 Munechikayanagikoku, Kurose-cho, Higashihiroshima-shi, Hiroshima-ken, 739-2504, Japan

ARTICLE INFO

Article history:

Received 27 August 2021

Accepted 20 September 2021

Keywords:

Three-Dimensional Models

Pelvic Alignment

Pregnancy

Postpartum Period

A Case Report

ABSTRACT

3-dimensional pelvic models based on magnetic resonance images (MRI) can be used to investigate accuracy and specifics of changing pelvic alignment during pregnancy and after childbirth. Few studies have investigated changes of pelvic alignment during pregnancy and after childbirth using three-dimensional pelvic models. This case report documents the changes of pelvic alignment during late pregnancy and after childbirth using MRI-based three-dimensional (3D) pelvic models. This was a longitudinal observation case report. A woman was imaged with MRI at 28 and 39 gestational weeks, as well as 4 and 72 weeks after childbirth. Greater internal, anterior, and downward rotation of both innominates at week 39 was observed from that at gestation week 28. Decreased internal, anterior, and downward rotation of both innominates at week 4 after child birth was observed compared with that at gestation week 39. We report the first case in Japan of changes of pelvic alignment measured using an MRI-based 3D pelvic alignment model during pregnancy and after child birth. This case suggests that the small changes of pubic area and greater separation of anterior portions of sacroiliac joints. Internal, anterior, and downward rotation of both innominates was observed in a Japanese primipara woman having no pelvic pain.

© 2021 The Authors. Published by Elsevier Inc. on behalf of University of Washington.

This is an open access article under the CC BY-NC-ND license

(<http://creativecommons.org/licenses/by-nc-nd/4.0/>)

* Corresponding author. A. Sakamoto.

E-mail address: sakamotoas@nisikyu-u.ac.jp (A. Sakamoto).

<https://doi.org/10.1016/j.radcr.2021.09.053>

1930-0433/© 2021 The Authors. Published by Elsevier Inc. on behalf of University of Washington. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>)

Introduction

Excessive kyphosis and lumbar lordosis have been identified as features of changes in posture during pregnancy. As pregnancy progresses, abdominal distension, and the load imposed upon the spine and pelvis by the gravid uterus increase considerably [1,2]. The uterus shifts forward, changing the center of gravity and orientation of the pelvis [1,2]. Width of pubic symphysis (PS) increases during pregnancy and decreases after childbirth [3]. Morino et al. [4] found that pelvic asymmetry changed during pregnancy and that it was associated with sacroiliac joint pain. Asymmetrical pelvic alignment increases the tightness of the ligaments and muscles around the sacroiliac joints (SIJ), and stress applied to the asymmetrical SIJ induces pain [5]. Thus, measurement and assessment of changes of pelvic symmetry during pregnancy and after childbirth are crucial to investigating factors of pain.

Changes of pelvic alignment during pregnancy and after childbirth have been reported; however, little attention has been paid to the accuracy of measuring methods. A palpation meter (PALM) is one tool used to measure changes of pelvic symmetry during pregnancy and after childbirth. Previous studies show that the validity and reliability of PALM are high [6,7]. However, accurate palpation requires experience and good technique. Computed tomography (CT) and magnetic resonance imaging (MRI) are also utilized for pelvic measurement. CT discovers bilateral inferior and superior pubic symphyses, plane coordinates of bilateral highest points of iliac crests and furthest lateral points of acetabular margins [8]. MRI discovers abnormalities in the pubic area during pregnancy [9]. Although many previous studies have showed changes and separation of the pubic symphysis [10–14], few data are available on changes of sacroiliac joints [8,15,16]. We assessed pelvic alignment and sacroiliac joints using a three-dimensional (3D) pelvic model based on MRI in a pregnant woman during gestational weeks 28 – 39, and at 4 and 72 weeks after childbirth. This is the first such case reported in Japan.

Case presentation

Pelvic alignment of a healthy, 25 – year-old Japanese primipara woman was observed at 28 and 39 gestational weeks, and at 4 and 72 weeks after childbirth (Fig. 1). She was pregnant with her second baby (within the first 8 weeks) 72 weeks after the first childbirth. She did not have any serious disease history or difficulties in daily activity before or during pregnancy. She had no serious orthopedic disorders, or neurological or physiological diseases after childbirth. She did not complain of any lower back or pelvic pain during pregnancy or after childbirth. She gained 9 kg during pregnancy (before pregnancy, 52 kg; maximum weight during pregnancy, 61 kg; weight 4 weeks after childbirth, 53 kg). Her height was 167 cm. She delivered her baby by normal vaginal birth. The time of delivery was two hours and 38 minutes after labor pains commenced. The new baby did not have any physical problems, and weighed 2684 g.

She had no pain (numerical Rating Scale (NRS)=0) and her pelvic girdle questionnaire (PGQ) score was 0 at 28 and 39 gestational weeks, and at 4 and 72 weeks after childbirth. She did not complain about lower back or pelvic pain during pregnancy or postpartum.

3D pelvic model

MRI (1.5T, thickness 2 mm, Toshiba Co.) were obtained at 28 and 39 gestational weeks, a month and 18 months after childbirth. 3-dimensional (3D) bone models of the bilateral innominate and sacrum were produced using 3D-DOCTOR software (Able Software Corp., Lexington, MA). A 3D surface model of the pelvic girdle was created by segmenting the contours of the innominate and sacrum using DICOM data of MRI images with a slice thickness of 2 mm.

The number of polygons was reduced to 10,000 for both innominates to standardize the polygon distribution between the innominates and sacrum, and centroid coordinates of each innominate and the sacrum were obtained using Geomagic Studio 2013 (Geomagic, Inc., USA). A local coordinate

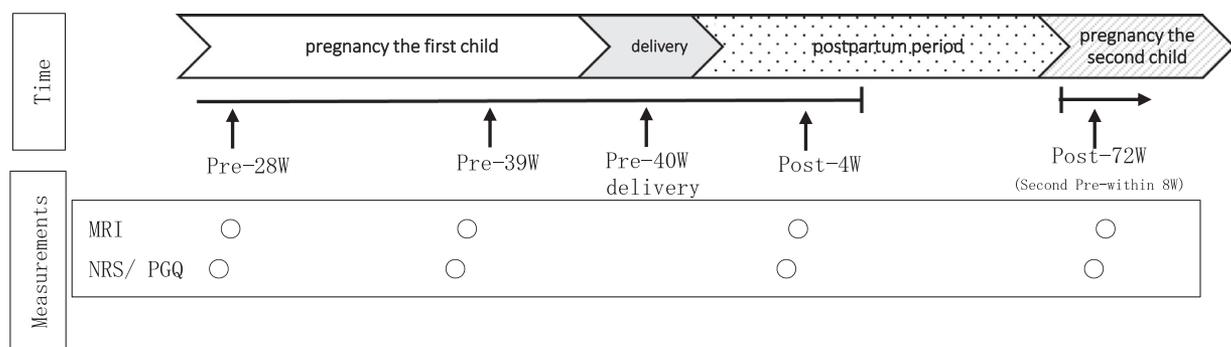


Fig. 1 – Protocol of observation and measurements. MRI was performed at 28 and 39 weeks pregnancy and 4 and 72 weeks after childbirth. Pelvic girdle pain and activity limitations were investigated with NRS and PGQ at the same time (circle: carries out). This case delivered at 40 weeks pregnancy. MRI: magnetic reasoning images, NRS: numeric rating scales of pelvic pain, PGQ: pelvic girdle questionnaire, Pre: pregnancy, Post: postpartum period

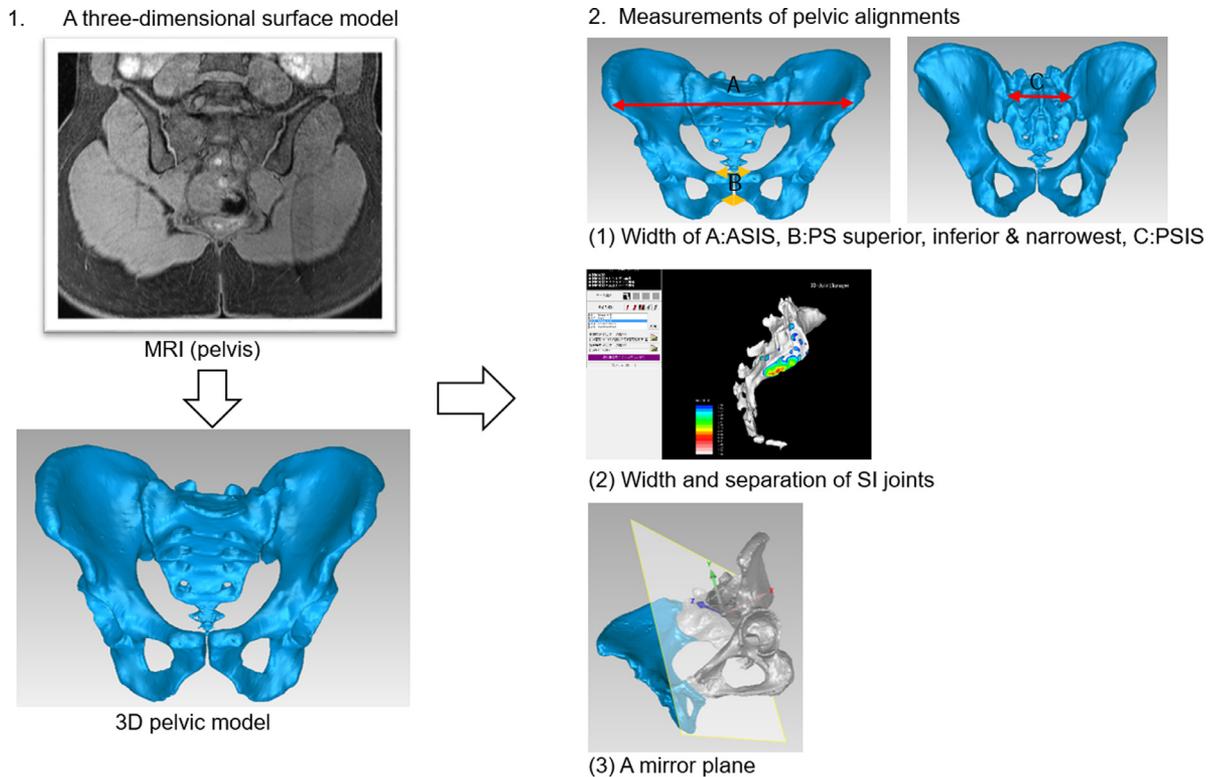


Fig. 2 – Processes of three dimensional pelvic model analysis. 1. A 3D surface model of the pelvic girdle was created by segmenting the contours of the innominates and sacrum using DICOM data of MRI images with a slice thickness of 2 mm. 2. (1) The distance of the lateral anterior superior iliac spin (ASIS)(A), the posterior superior iliac spin (PSIS)(C), the narrowest pubic symphysis (PS)(B), the superior PS and the inferior PS were measured with the measurement system in Geomagic studio 2013. (2) Separation of the sacroiliac joints (SI joints) was analyzed using 3D-Joint Manager software (GLAB, Japan). Areas of ≤ 4 mm between the surfaces of sacroiliac joints was colored. (3) A mirror plane was defined using both origins, centroids, and ASIS and the right innominate was flipped on the mirror plane, and a best-fit algorithm was used to obtain 6°-of-freedom alignment of both innominates at each time point

system was embedded at the center of the sacrum. First, the sacral midplane was defined using (1) the midpoint of the left and right superior articular processes, (2) the center of the sacral base, and (3) the center of the third sacral vertebra. Second, the origin was defined by the intersection of the sacral midplane and the cylindrical axis circumscribing the right and left auricular surfaces. The Z (transverse)-axis was defined by the line passing through the origin, perpendicular to the sacral midplane, the Y (vertical)-axis by the line connecting the origin and the center of the sacral base, and the X (sagittal)-axis was the cross-product of the Y and Z-axes.

The distance of the lateral anterior superior iliac spin (ASIS), the posterior superior iliac spin (PSIS), the narrowest pubic symphysis (PS), the superior PS and the inferior PS were measured with the measurement system in Geomagic studio 2013. The surface trim system was used to decide accuracy of target points.

A mirror plane was defined using both origins, centroids, and ASIS and the right innominate was flipped on the mirror plane, and a best-fit algorithm was used to obtain 6°-of-freedom alignment of both innominates at each time point (Fig. 2).

Separation of the sacroiliac joints (SI joints) was analyzed using 3D-Joint Manager software (GLAB, Japan). Areas of ≤ 4 mm between the surfaces of sacroiliac joints was colored. We observed changes of the colored gross areas during gestation and one and eighteen months after childbirth.

Changes of pelvic alignments

Distances between the PSIS and inferior PSs increased from 28 to 39 gestational weeks. Those distances decreased 4 weeks after childbirth. The distance between the ASISs, superior PSs, and the narrowest PS decreased from 28 to 39 gestational weeks. Those distances decreased even more from 4 to 72 weeks after childbirth. The ASIS and PSIS distances 72 weeks after the first childbirth (the second child pregnancy commenced within 8 weeks) were greater than those at 28 weeks of gestation and the distance of the sacroiliac joint and PS 72 weeks after the first childbirth were narrower than those at 28 gestational weeks (Fig. 3).

The width of the lateral ASIS changed slightly from 28 gestational weeks to 72 weeks after childbirth (Fig. 3). The width of the lateral PSIS increased about 3 mm from 28 gestation

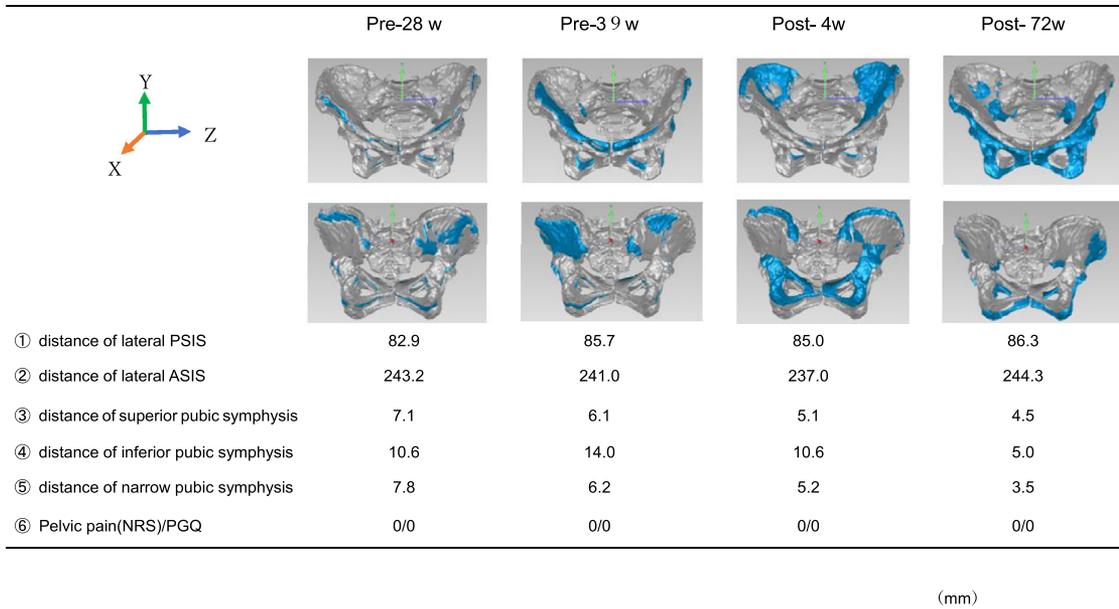


Fig. 3 – Width of lateral ASIS, PSIS and pubic symphysis as well as pelvic girdle pain. Changes in innominate rotation and translation to the sacrum from 28 weeks gestation to 72 weeks after childbirth ((blue color (current period)). Additionally, distances of lateral the posterior superior iliac spin (PSIS), the anterior superior iliac spin (ASIS), pubic symphysis and sacroiliac (SI) joint were changed from 28 weeks pregnancy to 72 weeks after childbirth. Pelvic pain was not appeared

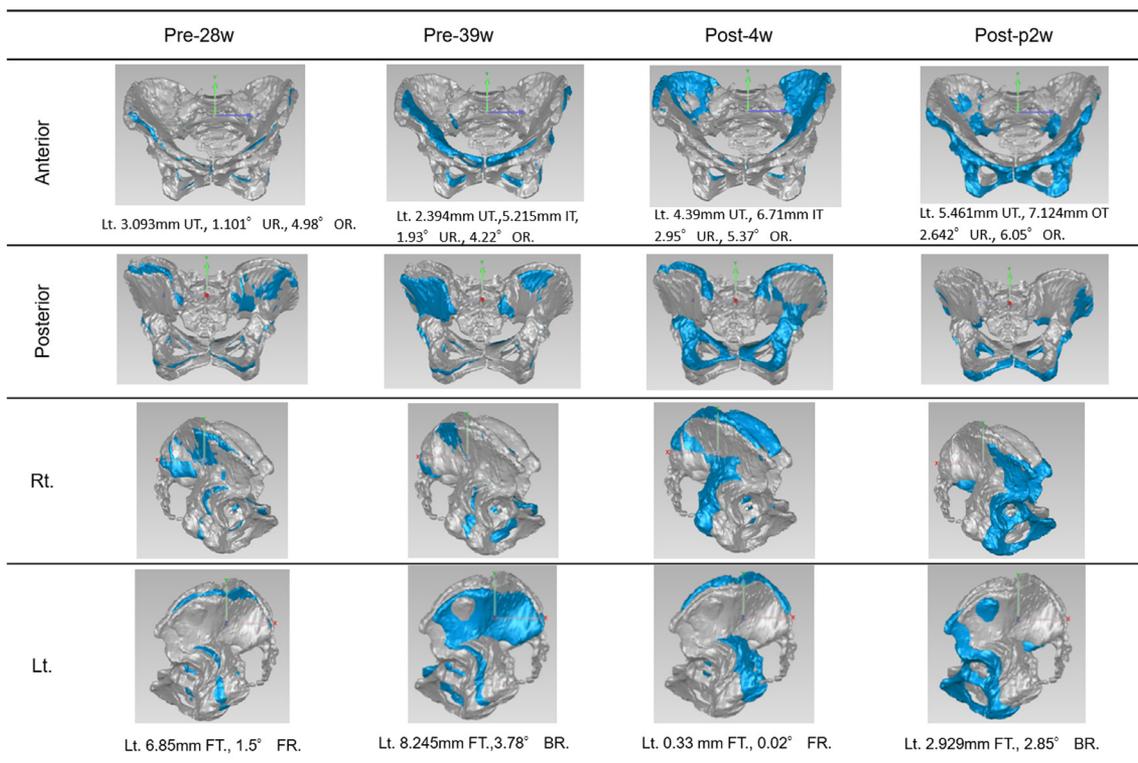


Fig. 4 – Changes of innominate rotation and translation around the center of the sacrum. Three dimensional pelvic models: The changes of pelvic alignments from 28 gestation weeks to 72 weeks after childbirth. To compare with each period (blue color (current period) vs gray color (other periods)) .Numbers indicate left innominate translation and rotation angles to right side. UT: upward translation, FT: forward translation, IT: inside translation, OT: outside translation, UR: upward rotation, OR: outside rotation, FR: forward rotation, BR: backward rotation

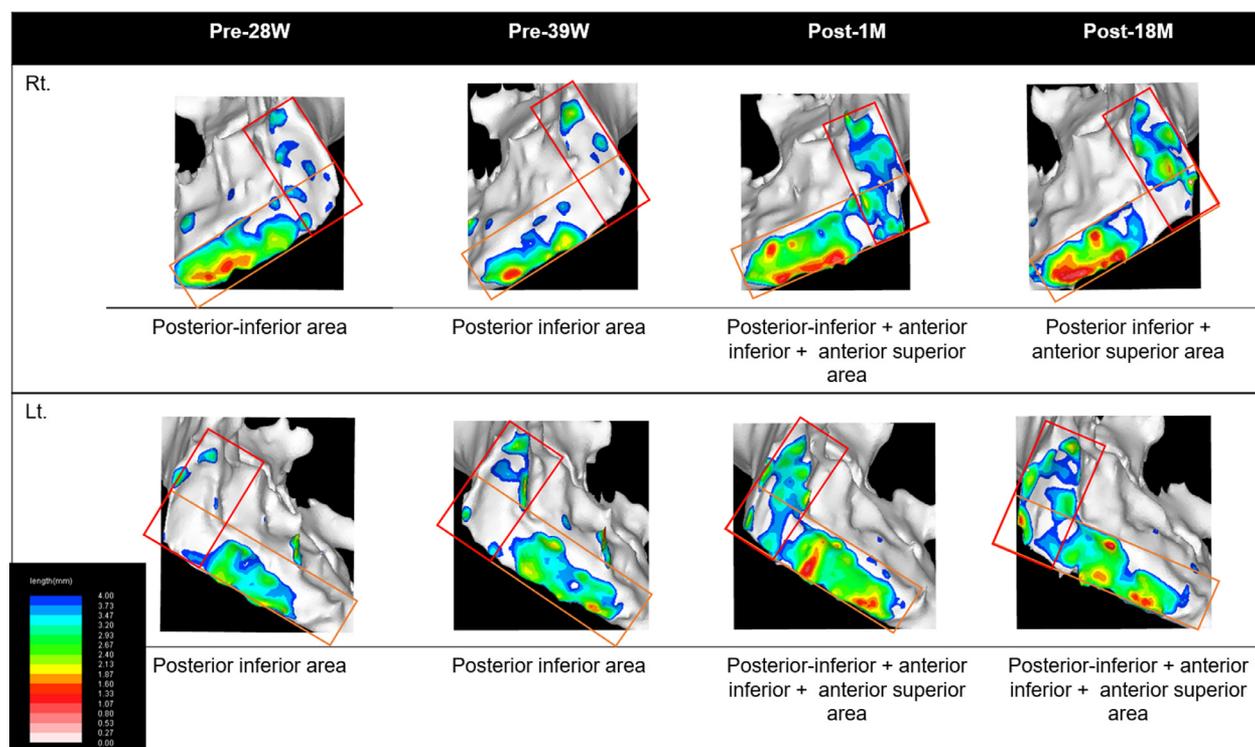


Fig. 5 – Changes in SI joints separation. Area of close distance of sacroiliac joints within 4mm. The separation of the left sacroiliac (SI) joint decreased from 28 to 39 gestational weeks reaching a maximum 4 weeks after childbirth. The right side SI joint separation increased from 28 to 38 gestational weeks. The separation of anterior portions of each sacroiliac joint widened during pregnancy (see red quadrangle area)

weeks to 39 gestation weeks. The width of the PS showed a small change (Fig. 3).

Both innominates rotated anteriorly, downward, and internally from 28 to 39 gestational weeks, and posterior, upward, and external rotation appeared 4 weeks after childbirth. Both innominates rotated slightly anteriorly, downward, and externally from 4 weeks to 72 weeks after childbirth (Fig. 3).

Asymmetry of pelvic alignment, comparing the left innominate relative to the right innominate around the center of the sacrum, and displacements of translation and rotation of both innominates at each time point are shown in (Fig. 4). Rotation of the left side was greater than that of the right side. The left innominate was translated farther downward from 28 to 39 gestational weeks compared with that of the right side. The left innominate was gradually translated anteriorly after 28 gestational weeks compared to the right side. Downward rotation of the left innominate increased from 28 gestational weeks to 4 weeks after childbirth. The left anterior pelvic tilt increased until 39 gestational weeks and decreased after childbirth.

The separation of the left SI joint (≤ 4 mm) decreased from 28 to 39 gestational weeks reaching a maximum 4 weeks after childbirth. The right side SI joint separation increased from 28 to 38 gestational weeks (Fig. 5). The separation of anterior portions of each sacroiliac joint widened during pregnancy.

Over all, although the change of pubic area was small, greater loosening of SI joints, especially their anterior por-

tions, and innominate rotation were observed. In addition, changes in SI joints occurred asymmetrically.

Discussion

Anterior and sagittal pelvic alignments during pregnancy and 1 month after child birth changed [15]. PS separation, SI joint replacement, and pelvic fracture are serious complications that may occur during delivery [9,13]. Natural changes of pelvic alignment during pregnancy and a month after childbirth have been reported in several previous studies that employed palpation measurement [15,16]. This is the first report to observe changes of innominate rotation and translation and separation of SI joints during pregnancy and after childbirth using MRI-based 3D pelvic models. Changes of innominate rotation and translation and separation of SI joints may be due to the alignment pattern before pregnancy, as well as laxity and habitual postures and/or movements. Morino et al. [15] found that the anterior pelvis became significantly wider as pregnancy progressed and the anterior width of the pelvis a month after childbirth was wider than at 12 weeks of pregnancy, although the posterior width did not differ significantly [15]. The anterior width of the pelvis had not recovered 1 month after childbirth and was still wider than at 12 weeks gestation [15]. Morino et al. [15] also showed that the anterior pelvic tilt increased during pregnancy and decreased

after childbirth [15]. Our results confirmed those of Morino et al. [15]. The width of the ASISs a month after childbirth was greater than that at 28 gestation weeks. Ji et al. [8] found the distance between the two sides of the furthest lateral points of the acetabular margins (FLAM) was significantly lower 1-month postpartum than just after delivery. The width of PS separation also illustrated a significant shortening a month after parturition. In the axis direction of the pelvis, images taken one month postpartum revealed a significantly smaller translation of the PS, compared with images immediately postpartum [8]. There were no significant changes in the distance between HICs or the PSS angle [8]. We found that the innominate showed downward rotation and abduction from 28 to 38 gestational weeks and upward rotation and adduction after childbirth. In addition, although the width of ASIS was only slightly wider during the pregnancy, the area of closest distance of SI joints >4 mm in left SI joint increased from 28 gestation weeks to 38 gestation weeks and became maximal a month after childbirth. Thus, innominate rotation and SI joint separation occur as natural changes of pelvic alignment in pregnancy with no lower back or pelvic pain.

In this case, results showed asymmetrical innominate alignment, as in a previous study [15]. The left innominate rotated to a greater external angle than the right side. In addition, greater separation of the left SI joint was observed compared with the right side. Yamaguchi et al. [16] found that pelvic asymmetry of pregnant women and postpartum women was greater than that of women who had never been pregnant. The anterior width of the pelvis of pregnant women was wider than that of women who had not borne children, while the posterior width of pelvis (SI joints and the width of PSIS) in pregnant women were narrower than those of women who had never been pregnant [16]. Damen et al. [5] found that asymmetrical ligament relaxation during pregnancy was also associated with pelvic girdle pain in postpartum women. However, asymmetrical changes of the pelvis may also occur in non-symptomatic pregnancy. The degree of asymmetrical changes may also be associated with pelvic girdle pain. Further study is needed to investigate the association between pelvic alignment changes and pain. In future studies, we will compare pelvic alignment between women who experience pain and those who do not, in order to determine the association between pelvic alignment and PGP in pregnant and postpartum women.

Patient consent

Informed consent for patient information to be published in this article was obtained.

REFERENCES

- [1] House M, McCabe R, Socrate S. Using imaging-based, 3-dimensional models of the cervix and uterus for studies of cervical changes during pregnancy. *Clin Anat* 2013;26:97–104 PubMed PMID: 23168534.
- [2] Nott JP, Bonney EA, Pickering JD, Simpson NAB. The structure and function of the cervix during pregnancy. *Transl Res Anat* 2016;2:1–7.
- [3] Aydin S, Bakar RZ, Aydin CA, Ozcan P. Assessment of postpartum symphysis pubis distention with 3D ultrasonography: a novel method. *Clin imaging* 2016;40:185–90 PubMed PMID: 26995568.
- [4] Morino S, Ishihara M, Umezaki F, Hatanaka H, Yamashita M, Aoyama T, et al. Pelvic alignment risk factors associated with sacroiliac joint pain during pregnancy. *Clin Exp Obstet Gynecol* 2018;45(6):850–4.
- [5] Damen L, Buyruk MH, Guler-Uysal F, Lotgering KF, Snijders JC, H SJ. Pelvic pain during pregnancy is associated with asymmetric laxity of the sacroiliac joints. *Acta Obstet Gynecol Scand* 2001;80:1019–24.
- [6] Petrone RM, Guinn J, Reddin A, Sutlive GJ, Flynn WT, Garber AM. The accuracy of the palpation meter (PALM) for measuring pelvic crest height difference and leg length discrepancy. *J Orthop Sports Phys Ther* 2003;33:319–27.
- [7] Azevedo DC, Santos H, Carneiro RL, Andrade GT. Reliability of sagittal pelvic position assessments in standing sitting and during hip flexion using palpation meter. *J Bodyw Mov Ther* 2014;18:210–14.
- [8] Ji X, Takahashi M, Morino S, Takakuwa T, Iijima H, Zhang X, et al. Postpartum radiographic changes in pelvic morphology and its relation with symptoms of pregnancy-related symphysis pain. *Clin Exp Obstet Gynecol* 2018;5:665–70.
- [9] Miller JBA, Low LK, Zienski R, Smith AR, DeLancey JO, Brandon C. Evaluating maternal recovery from labor and delivery: bone and levator ani injuries. *Am J Obstet Gynecol* 2015;213(2):188.e1–188.e11.
- [10] Qiao J, Qin J, Feng J, Huang M, Xia P. Relationship between pubic symphysis separation and postpartum pelvic girdle pain: a retrospective study of 32 cases. *PM & R: journal of Inj, Funct, and Rehabil* 2020;12(12):1222–6 PubMed PMID: 32030890.
- [11] Islam MA, Ali MA, Beg A, Chowdhury F, Ansary NB, Quddus MA, et al. Post partum diastasis of the pubic symphysis: a case report. *CBMJ* 2013;2:73–5.
- [12] Cowling PD, Rangan A. A case of postpartum pubic symphysis diastasis. *Injury* 2010;41:657–9 PubMed PMID: 20152970.
- [13] Cicek H, Keskin HL, Tuhanioglu U, Kilicarslan K, Ogur HU. Simultaneous disruption of the pubic symphysis and sacroiliac joint during vaginal birth. *Case RepOrthop* 2015;2015:1–5 812132. PubMed PMID: 26078900. Pubmed Central PMCID: 4452851.
- [14] Mahajan A, Gupta I, Verma P. Split apart postpartum: a case report of post partum pubic symphysis diastasis. *Int J Med Rev Case Rep* 2019;3(8):555–7.
- [15] Morino S, Ishihara M, Umezaki F, Hatanaka H, Yamashita M, Aoyama T. Pelvic alignment changes during the perinatal period. *PLoS One* 2019;14:e0223776 PubMed PMID: 31600310. Pubmed Central PMCID: 6799872 Corporation. However, the funder only provided support in the form of salaries for authors [FU, HH and MY], but did not have any additional role in the study design, data collection and analysis, decision to publish, or preparation of the manuscript. Moreover, this does not alter our adherence to PLOS ONE policies on sharing data and materials.
- [16] Yamaguchi M, Matsumoto D, Morino S, Nishiguchi S, Fukutani N, Tashiro Y, et al. Comparison of pelvic alignment among never-pregnant women, pregnant women, and postpartum women (pelvic alignment and pregnancy). *J Women's Health Care* 2016;5:1–5.