Comparing the pelvis of Tibetan and Chinese Han women in rural areas of China: two population-based studies using coarsened exact matching

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Comparing the pelvis of Tibetan and Chinese Han women in rural areas of China: two population-based studies using coarsened exact matching

This study aims to investigate the difference of pelvic size and shape between Tibetan and Chinese Han women. Data on pelvic dimension measures including interspinous diameter (IS), intercrestal diameter (IC), external conjugate (EC) and transverse outlet (TO) were acquired from two population-based studies among Tibetan women in Lhasa, and Chinese Han women in Shaanxi province in China. After coarsened exact matching, there was no statistical difference between any characteristics among Tibetan and Chinese Han women ($p>0.05$). The generalized estimating equation models showed Tibetan women had significantly lower IS and IC means than Chinese Han women (IS: 24.39cm vs 24.77cm, $p<0.001$; IC: 26.35cm vs 26.93cm, $p<0.001$) but statistically higher in TO mean (9.12cm vs 9.03cm, $p<0.001$). This study showed Tibetan women have smaller pelvis compared to Chinese Han women. This should offer a useful literature on the comparison of pelvis between Tibetan and Chinese Han women although the difference is small.

Keywords: pelvis; Tibetan women; Chinese Han women; coarsened exact matching; population-based study

Impact statement:

• What is already known on this subject?

Response: Previous studies in China indicated different populations have different dimensions of pelvis, with the pelvis of Uighur women being bigger than Chinese Han women, and that of Zhuang and Tu women being smaller than Chinese Han women. Little research reports the specific size of Tibetan women's pelvis. Living at high altitude, the Tibetan population have differentiated demographics and show local adaptions, such as unelevated hemoglobin, and significant catch-up growth for infants compared with Chinese Han infants. Therefore there is a strong rationale for better understanding pelvic characteristics amongst this population.

• What do the results of this study add?

Response: This study showed Tibetan women have smaller pelvises compared to Chinese Han women. Tibetan women have a smaller interspinal diameter and intercrestal diameter than Chinese Han women, which leads to relatively narrow hip.

• What are the implications of these findings for clinical practice and/or further research?

Response: This study provides useful comparative information on pelvic features between Tibetan and Chinese Han women although the findings of differences were small. In addition, during the formulation of women's health policy, the results of this study can provide data to support the selection of appropriate indicators of obstetrics and gynecology for different populations of pregnant women during antenatal care and delivery.

Introduction

The pelvis has been a bone of considerable interest with research continuing to refine our understanding of the anatomy, development and function of the human pelvis (DeSilva and Rosenberg, 2017, Tateuchi et al., 2020, Jeppson et al., 2018). The human pelvis is well-adapted for the rigors of bipedal locomotion and uniquely shaped, it is super inferiorly short and stout (Rosenberg and Desilva, 2017). For humans, the pelvis plays a number of important functions; it is the birth canal through which the human neonate must pass, and both the pelvic floor musculature and the pelvis itself support the abdominal organs (Pavlicev et al., 2020, DeSilva and Rosenberg, 2017). Numerous morphometric studies identify how the dimensions of the pelvis differ between populations all over the world (Kurki and Decrausaz, 2016). For example, healthy white women have a larger bony pelvis than non-white women (Rizk et al., 2004), and the posterior pelvic floor area of African American women is smaller than that of European American women (Baragi et al., 2002).

China is a multi-people country, the largest group being the Chinese Han. There are significant differences in environment, lifestyle and even genetic composition among different populations. Previous studies in China, in the region of Xinjiang, indicated that the Uighur female pelvis is bigger than that of the Chinese Han female (Ke et al., 2013), and the pelvis of

Zhuang and Tu women are smaller than Chinese Han women (Ni et al., 1989, Bo and Zheng, 1989). Living at high altitude, the Tibetan population have differentiated demographics and show local adaptions (Zhang et al., 2017). In order to cope with their tremendously hypoxic environment this population possesses a distinctive set of adaptive physiological traits, such as unelevated hemoglobin, and significant catch-up growth for infants compared to the Chinese Han (Beall et al., 2010, Wang et al., 2016). However, there is a lack of research on the specific size and shape of Tibetan women's pelvis. Pelvic disproportion accounts for 2%-15% of pregnancies and is associated with significant maternal and fetal complications, therefore antenatal prediction of this condition is essential for decreasing its contribution to obstetric mishaps (Melah et al., 2003).

In this study, we aimed to compare the pelvic size and shape between populations of Tibetan and Chinese Han women, to provide a reference point for further pelvic studies. There are two key strengths in general. Firstly, the data were drawn from two population-based cohort studies in rural area of China and they were Tibetan and Chinese Han pregnant woman cohort, respectively. Secondly, it is the first study in western China to show the specific magnitude of the difference between Tibetan and Chinese Han women.

Materials and Methods

Study design

Data were drawn from two population-based cohort studies investigating micronutrient supplementation among pregnant women. These include Tibetan women in rural Tibet region and Chinese Han women in the rural Shaanxi province. A subset of the data on pelvic dimensions was analyzed in this study. The study sample consisted of pregnant women aged 15-49 years old who were living in rural areas of the study site. They were followed from 20-28 weeks of gestation to delivery. During the period of follow-up, three interviews were scheduled Basic socioeconomic information and pelvic dimensions were collected during the first interview, then maternal weight, hemoglobin level, blood pressure, heart rate, type of

delivery and other information were collected at each interview during the follow-up. The interviews were conducted by a member of trained maternal and child health care staff from the county hospitals. The detailed information on study design and interviews has been reported elsewhere (Zeng et al., 2008, Kang et al., 2017). Both Shaanxi and Tibet regions are located in western China, which consists of 12 provinces with a number of minority groups (Dang et al., 2014). The Changwu and Bin counties in Shaanxi province were selected as one study site, where 99.5% of the population being of the Han ethnic group (Zeng et al., 2008). The Lhasa area, selected as the other study site, is located in the middle of the Tibet region, and is home to a large proportion of the Tibetan population. Two counties, including Chushur and Taktse, and 4 rural communes of Lhasa city were selected. The mean altitude of the Shaanxi rural study site is 1000 m above sea level, compared to 3706 m above the sea level for the Lhasa study area (Kang et al., 2017). Therefore the contrast in environmental conditions is a major variable between the female Tibetan and Chinese Han populations compared in this study. The authors assert that all procedures contributing to this work comply with the Helsinki Declaration of 1975, as revised in 2008, and has been approved by the Ethnical Committee of Xi'an Jiaotong University, China (Tibetan study: No 20070712; Chinese Han study: No 2002001).

Study women

In the primary study, women aged 15-49 years living in rural areas of each study site were investigated but only women aged 20-49 years were included in this study. This range was selected because below the age of 20 the pelvis may not have fully completed development, which could bias the pelvic measurements (Verbruggen and Nowlan, 2017, Huseynov et al., 2016). In total, 995 Tibetan women and 4804 Chinese Han women aged more than 20 years old were included for comparison of pelvic dimensions (Figure 1).

Measurement of pelvis

In this study, pelvic dimensions were measured by trained researchers using a pyelometer (Shanghai Jinzhong Medical Devices Co. LTD, Type of F30040) either at hospital/clinic or at

the participants' home. According to the values reported by Cao (Cao, 2006), the interspinal diameter (IS) is the distance between the anterior superior iliac spine, with the normal value in the range 23cm-26cm. The intercrestal diameter (IC) is the maximum width across iliac crests with a normal value of 25cm-28cm. The external conjugate (EC) is the distance between the pubic symphysis and spinous process of the 5th lumbar vertebra and the normal range is 18cm-20cm. The transverse outlet (TO) is the distance of the two ischial tuberosity's inside edge when a woman is in supine position (bending her legs and holding her knees with her hands) with the normal value of 8.5cm-9.5cm.

The assessment of the pelvis was divided into size and shape, as size is driven by the absolute pelvic dimensions (IS, IC, EC and TO) and shape is represented by relative pelvic dimensions. As one of the pelvic shapes, contracted pelvis was the focus of more attention because of the influence on delivery. Based on the external pelvic dimensions, three types of contracted pelvis can be defined, flat pelvis, funnel shaped pelvis and generally contracted pelvis. Flat pelvis was defined where the EC of the pelvis is less than 18cm, and generally contracted pelvis was defined as 2cm smaller dimension than normal values for the four pelvic dimension measures. Due to missing measurements for the angle of the pubic arch, in this study the funnel shaped pelvis was defined as only TO being less than 8cm (Meng, 2012, Bansal et al., 2011).

Quality control

The same inquiring and measuring methods were used for both studies and unified before the formal investigation. In order to ensure accuracy, equivalence and reliability in the results of the pelvic measurements, the experts from the Maternal and Child Health Care Hospital in Lhasa and Shaanxi were invited to train MCH staff, who were responsible for the pelvic measurement of the participants. In the Tibetan cohort study, a standardized Tibetan-Chinese bilingual questionnaire was used to collect the information.

Statistical analysis

Coarsened exact matching (CEM) was used to keep better balance of distributions of the

confounders (such as maternal age, height, weight, BMI and infant's weight, length) between two populations (Iacus et al., 2011). These confounders were selected based on commonly recognized measures and the characters of the native Tibetan and Chinese Han participants identified in various studies (Wells et al., 2017, Abitbol, 1996). As reported in Figure 1, a total of 875 Tibetan women and 4039 Chinese Han women were available for our study after coarsened exact matching. In our analysis plan, pelvic size and pelvic shape were mainly used to compare the difference of the two populations (Figure 1). Categorical variables were reported as percentages, T-tests, variance analysis and χ^2 tests were used for the univariate analysis. A generalized estimating equation (GEE) model was used for the comparison of the four dimensions of pelvis between two populations matched by CEM. In order to ascertain further the stability of difference in IS, IC, EC, TO between two populations, several sensitivity analyses were carried out by using adjusted models. The first model of sensitivity analyses attempted to ascertain whether the difference changes after adjusting for maternal age, height, weight and BMI by the generalized estimating equation model (model 1). The second model controlled for infant weight and length (model 2) and the model 3 adjusted for the all variables in model 1 plus model 2. Figures were created with Excel 2012. All analyses were performed using STATA statistical software version 10.0 (StataCorp LP, College station 77845, USA). A two-tailed *P* value <0.05 was considered statistically significant.

Results

Basic characteristics before and after matching

Statistically significant differences (p <0.05) were found between Tibetan and Chinese Han women for most of the basic characteristics (maternal height, weight, BMI, infant birth weight and length), with the exception being maternal age (p =0.129). After coarsened exact matching, there was no statistical difference on any characteristics between the Tibetan and Chinese Han women (p >0.05), which infers that good matching was achieved and thus different groups were now comparable.

Comparing the pelvic size of two populations

The distribution of Tibetan and Chinese Han women's IS, IC, EC and TO among maternal age, height, weight, BMI, infant's weight and length are shown in Table 1. The mean IS and IC of Tibetan women were lower than Chinese Han while higher in the mean TO among maternal age, height, weight, BMI, infant's weight and length (p <0.001). The mean EC of Tibetan women was similar to Chinese Han women across all different maternal and infant variables (p >0.05). Results from the generalized estimating equation models for the four pelvic dimensions and their comparison between the two populations are shown: Tibetan women had significantly lower mean IS and IC than Chinese Han women (IS: 24.39cm vs 24.77cm, P<0.001; IC: 26.35cm vs 26.93cm, p <0.001) but slightly higher mean TO (9.12cm vs. 9.03cm, p <0.001). There was no significant difference in mean EC between the two populations (18.83cm vs. 18.83cm, p =0.655). In terms of the magnitude of the differences, where significant, the mean IS and IC were therefore smaller for Tibetan women compared to Chinese Han women, with IS smaller by 0.38 cm and IC smaller by 0.58 cm. In contrast, mean TO was larger by 0.10 cm compared to Chinese Han women.

Sensitivity analyses results are shown in Figure 2. Three adjusted models indicated that Tibetan and Chinese Han women were still found different in IS, IC and TO but similar in EC after adjusting for potential confounding covariates. This suggests that the difference in pelvic dimensions between two populations remained even after changing the analysis methods.

Comparing the pelvic shape of two populations

Generally, two types of contracted pelvis were found among both the Tibetan women and Chinese Han women. A total of 59 (6.18%) flat pelvises were found in Tibetan women and 147 (3.28%) in Chinese Han women (χ^2=18.24, p <0.001). Two (0.21%) cases of funnel shaped pelvis were found in Tibetan women and 7 (0.16%) in Chinese Han (χ^2=0.14, p =0.712). There were no cases of generally contracted pelvis found in either the Tibetan or Chinese Han women. However, our study found that 12 (1.26%) of the Tibetan women had a smaller dimension in

IS, compared to 13 (0.29%) to Chinese Han women. For IC, 9 (0.94%) Tibetan women had a smaller dimension, compared to 14 (0.31%) among the Chinese Han. For EC, 24 (2.52%) Tibetan women had a smaller dimension, compared to 28 (0.62%) among Chinese Han women.

Discussion

The current study found that the pelvis of Tibetan and Chinese Han women showed marked differences, with Tibetan women having a smaller pelvis compared to Chinese Han women. The smaller pelvis might be to the differences in the characteristics between the populations. Previous studies had evidenced that different populations often developed variation in pelvic dimensional characteristics that might be attributed to differing environmental, cultural and lifestyle factors (Ke et al., 2013, Ni et al., 1989, Schwab et al., 2006). From the view of environmental adaptation and evolutionary adaption, several human populations, including the Tibetans, had survived for millennia at high altitudes, resulting in unique physiological features (Alkorta-Aranburu et al., 2012, Moore et al., 2001). In other studies, Handa et al (2008) reported that the pelvic inlet among white women could be 0.7cm wider than for African-American women (10.7cm vs 10.0cm), whereas Rizk et al., (2004) reported that the transverse diameter of the levator hiatus for white women was 2mm and 3mm longer than for Emirati and other Arab groups. In African American women, the posterior pelvic floor area was 889.6cm^2, which was smaller compared to European American women (937.0 cm^2) (Baragi et al., 2002). Around China, the mean of EC and TO among the women of Tu population was 0.39cm and 0.20cm smaller than Chinese Han women(Bo and Zheng, 1989). The sagittal entrance diameter of the Xinjiang Han group were increased (52.79mm vs 47.70mm) and the conjugate of the inlet decreased (115.26mm vs 122.40mm) compared with that of the South Han group(Ke et al., 2013). The TO of Zhuang women in Guangxi was 11.91cm which was 1.20cm and 1.34cm smaller than the corresponding measurement in Yao and Mulao women (13.11cm, 13.25cm) respectively, whereas the difference in other diameters was not statistically significant (Ni et al., 1989).

Our study provided evidence that the physical constant value of the pelvis of Tibetan women could have its own characteristic dimensional form. Compared to Chinese Han women, Tibetan women had smaller IS and IC, which led to relatively narrow hips. A related study indicated that the weight and height of Tibetan newborns were significantly smaller than Chinese Han newborns, and found that the ponderal index of Tibetan newborns was bigger than Chinese Han newborns(Wang et al., 2016). The ponderal index of newborns was an important indicator to assess asymmetrical intrauterine growth retardation(Cai et al., 2013). This evidence pointed to the fact that although smaller pelvises in Tibetan women might be an adaption to high altitudes it did not affect infant delivery negatively; a small fetus might be a result of adaption to such pelvis. Based on the existing criteria (Meng, 2012, Bansal et al., 2011), this study found lower percentages of contracted pelvis among Tibetan and Chinese Han women. The occurrence of flat pelvis seemed to be higher in Tibetan women than Chinese Han women, which was far more likely to be a result of small pelvis size.

The pelvic dimension including IS, IC, EC and TO was one method used for assessment of contracted pelvis. Whilst this method was easier to implement it may ignore other parameters. Factors such as gestational weeks, fat thickness and the posture of women when measuring the distance of the two ischial tuberosity's inside edge may affect the measurements of external conjugate and transverse outlet (Laster, 1974). Iida et al. suggested that the contracted pelvis should be defined by measures such as the area of the pelvis inlet and the sacral shape (Iida and Takahashi, 1993). When standard obstetric measurements were taken and compared to four additional medieval skeletal samples from Sudan, and to modern American standards for the same obstetric dimensions, the Sudanese Kulubnarti pelvis were smaller in most dimensions (Sibley et al., 1992). Studies had illustrated that the accuracy of clinical evaluation of the pelvic outlet is lower than when compared to X-ray pelvimetry, and the parameters of lesser pelvises could be better measured by an ultrasonic (Floberg et al., 1986, Kramarskii and Krasin, 1991). Therefore, further assessments of the pelvis of Tibetan women would be required and caution was needed when estimating or comparing the incidence of contracted pelvis in Tibetan women.

Limitations

Firstly, the data on the non-respondents were not available due to poor traffic in rural areas of Tibet and Shaanxi, which might cause some degree of sampling bias. Secondly, the external diameter of the pelvis was measured in order to infer the internal pelvis diameter but measurement errors cannot be excluded. Thirdly, potential determinants such as lifestyle and nutrition were not included in this study. More evidences based on comparison of other pelvimetric studies of populations from low and high altitude environments elsewhere are needed to clarify the differences in the next research steps.

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Declaration of interest statement

The authors declare no conflict of interest.

Data availability statement

The datasets generated for the current study are available from the corresponding author on reasonable request.

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Table 1. Distribution of pelvic dimension of Tibetan and Chinese Han women by maternal and infant characteristics

Figure 1. Study flow chart

Figure 2. Sensitive analysis of the difference in pelvic dimensions between Tibetan and Chinese Han women after controlling for maternal and infant's variables

Table 1 Distribution of pelvic dimension of Tibetan and Chinese Han women by maternal and infant characteristics

	IS		IC		EC		TO	
	Tibetan	Chinese Han	Tibetan	Chinese Han	Tibetan	Chinese Han	Tibetan	Chinese Han
Maternal variables								
Maternal age (years)								
≤25	24.37±1.31	24.67±1.10	26.30±1.37	26.84±1.10	18.85±1.47	18.79±0.68	9.08±0.67	9.00±0.45
≥26	24.41±1.28	24.86±1.13	26.41±1.30	27.02±1.14	18.85±1.15	18.88±0.72	9.17±0.66	9.06±0.45
Weight (Kg)								
≤50	24.44±1.43	24.50±1.12	26.40±1.43	26.61±1.11	18.87±1.20	18.61±0.75	9.10±0.65	8.92±0.45
51-55	24.35±1.11	24.77±1.05	26.37±1.19	26.94±1.05	18.87±1.39	18.88±0.63	9.22±0.67	9.06±0.42
≥56	24.39±1.31	25.10±1.11	26.30±1.35	27.31±1.11	18.82±1.35	19.07±0.63	9.08±0.68	9.14±0.44
Height (m)								
≤1.57	24.28±1.35	24.53±1.16	26.22±1.41	26.67±1.17	18.74±1.28	18.67±0.74	9.05±0.72	8.96±0.45
1.58-1.60	24.26±1.18	24.76±1.04	26.15±1.22	26.90±1.04	18.85±1.50	18.85±0.61	9.06±0.64	9.03±0.44
≥1.61	24.55±1.31	25.01±1.09	26.56±1.33	27.21±1.07	18.92±1.21	18.99±0.70	9.22±0.64	9.10±0.43
BMI (Kg/m^2)								
≤18.5	24.39±1.42	24.50±1.09	26.49±1.25	26.63±1.11	18.74±1.14	18.63±0.75	9.13±0.57	8.92±0.46

18.5~	24.37±1.29	24.76±1.11	26.31±1.33	26.93±1.11	18.83±1.30	18.84±0.67	9.12±0.68	9.03±0.44
≥24	24.77±1.15	25.22±1.16	26.82±1.37	27.38±1.22	19.34±1.74	19.16±0.96	9.27±0.69	9.14±0.46
Infant variables								
Birth weight (g)								
≤3000	24.39±1.29	24.70±1.10	26.35±1.32	26.87±1.13	18.83±1.34	18.79±0.67	9.10±0.65	9.01±0.44
≥3001	24.39±1.38	24.81±1.12	26.35±1.39	26.99±1.10	18.87±1.32	18.87±0.65	9.17±0.69	9.04±0.44
Birth length (cm)								
≤50	24.33±1.26	24.72±1.11	26.27±1.28	26.90±1.12	18.84±1.28	18.85±0.67	9.09±0.65	9.03±0.45
≥51	24.60±1.49	24.89±1.12	26.61±1.56	27.06±1.09	18.92±1.47	18.83±0.61	9.29±0.71	9.00±0.41

IS: interspinal diameter; IC: intercrestal diameter; EC: external conjugate; TO: transverse outlet.

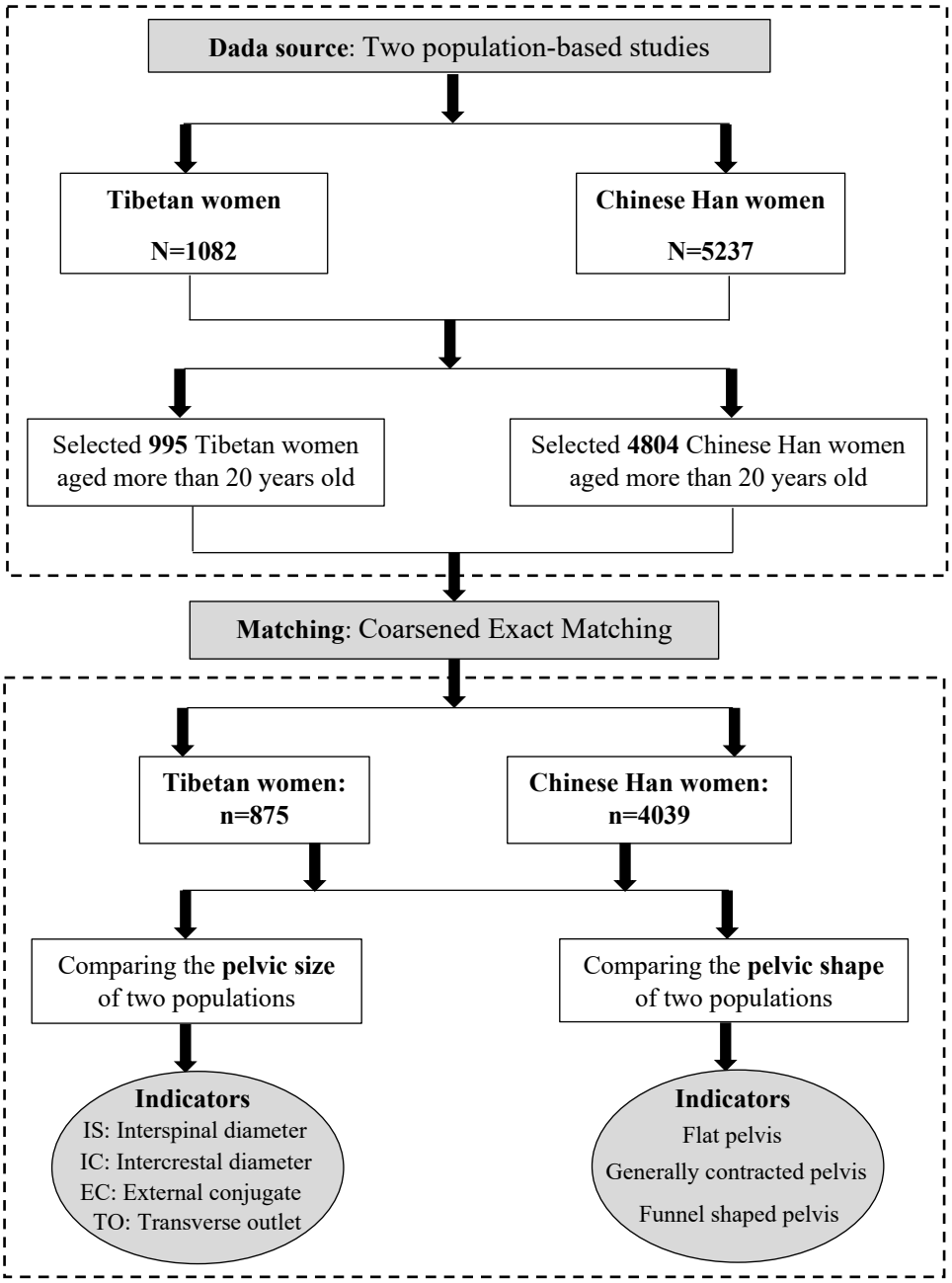

Figure 1 Study flow chart

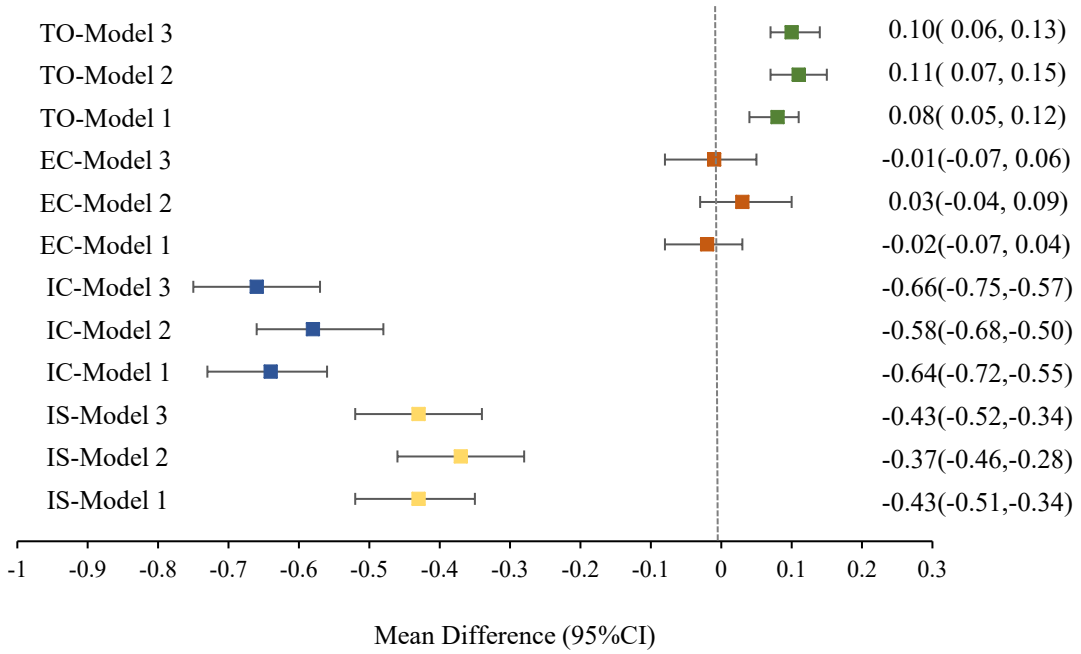

Figure 2 Sensitive analysis of the difference in pelvic dimensions between Tibetan and Chinese Han women after controlling for maternal and infant's variables.

Note: IS=interspinal diameter, IC=intercrestal diameter, EC=external conjugate, and TO=transverse outlet. Model 1 was adjusted for maternal age, height, weight, BMI, model 2 adjusted for infant's weight and length and model 3 adjusted for the all variables in model 1 plus model 2.