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ORIGINAL ARTICLE

Anthropometric measurements in the diagnosis of pelvic size: an analysis of maternal height and shoe size and computed tomography pelvimetric data

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Abstract
Background To determine whether measurements of maternal height and shoe size are predictors of pelvic size, using erect lateral computerized tomography (CT) pelvimetry as gold standard.
Materials and methods Three hundred and fifty three obstetric patients out of a sequential population of 6112 (5.8%) had CT pelvimetry performed between January 1990 and December 1991 at the Department of Obstetrics and Gynecology, York District Hospital, United Kingdom. Multivariable logistic regression models were built using maternal height ($n = 322$), shoe size (314) and weight at last clinic visit ($n = 318$). The reference standard for pelvic size was CT Pelvimetry. Pelvic adequacy was defined as an anterior-posterior diameter of the inlet of $\geq$ 11 cm and an anterior-posterior diameter of the outlet $\geq$ 10 cm on erect lateral CT pelvimetry. Women with values lower than these were regarded as having an inadequate pelvis. The diagnostic accuracy of the models was determined by the area under the receiver operating characteristic curve (AUC).
Results The area under the curve (AUC) for maternal height (0.768) was not significantly greater than that for shoe size (0.686, $p = 0.163$ for the difference in AUC's) and weight at the last clinic visit (0.655, $p = 0.057$ for the difference in the AUCs). The change in the AUC for each of the models (the full model with height, shoe size and weight [0.769]; model for height and shoe size [0.767] model for just height [0.768]) was also not significantly different.
Conclusions Measurements of maternal height, shoe size and weight at the last clinic visit are not useful for the identification of women with inadequate pelvis.

Keywords Height · Shoe size · Weight · Pelvimetry · Pelvic size

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Introduction

X-ray pelvimetry was introduced early in the twentieth century for the evaluation of cephalopelvic relationships. Despite numerous modifications, data from multiple studies suggest that either X-ray pelvimetry is unnecessary or the information provided does not have any bearing on clinical decisions or the outcome of delivery [6, 11, 13, 20, 23]. X-ray pelvimetry does not predict the likelihood of vaginal delivery, in part because labor is a dynamic process with pelvic dimensions constantly changing relative to each other, making measurements between bony parts irrelevant.

Most maternity units record maternal height and weight, while some record shoe size because of the notion that mothers who have a short stature or who are small boned are more likely to have a "small" pelvis and therefore at risk of dystocia. However, maternal height, shoe size and weight have seldom been validated against pelvic measurements. Our literature search (PUBMED and OVID search 1963 to 2005) using key words including height, shoe size, weight, pelvic size; clinical, X-ray, CT and MRI pelvimetry; dystocia, cephalopelvic and fetal-pelvic disproportion; vaginal birth after cesarean, repeat cesarean; revealed a dearth of relevant studies evaluating the test performance of maternal height, shoe size and weight in determining pelvic size. Therefore, this study was undertaken to determine the accuracy of maternal height, shoe size and weight at the last clinic visit in the identification of pelvic size, using the acceptable minimal criteria [20] on erect lateral computerized tomography (CT) pelvimetry as a gold standard for the diagnosis of inadequate and adequate pelvis.

Materials and methods

A cohort study on 353 of the 6,112 obstetric patients who had CT pelvimetry at York District Hospital, in the UK between January 1990 and December 1991 was performed. Pelvimetric measurements were obtained by CT imaging. Detailed technical aspects of obtaining these measurements at York District hospital have been described [5]. Although, Russell and Richards [20] recommended that the minimum pelvic measurements for vaginal delivery in centimeters are a sagittal inlet of 11 or Biparietal diameter of the fetal head +0.5, transverse diameter inlet of 11.5, bispinous and sagittal diameters of the pelvic outlet of 9 and 10, respectively, the recognition of radiation hazards led obstetricians to abandon full pelvimetry for a single erect lateral view. Therefore, adequacy of the pelvic size for the purpose of this study was diagnosed from recordings of the anterior–posterior diameter of the pelvic inlet $\geq$11 cm and the anterior–posterior diameter of the pelvic outlet $\geq$10 cm from erect lateral CT pelvimetry. Those with values lower than these were regarded as having an inadequate pelvis. Of the 353 patients who had CT pelvimetry performed, one patient with congenital dislocation of the hip and 24 others with missing pelvimetric data were excluded. Of the remaining 328 patients included in the analysis, 314, 318, 322, 323, 327, and 328 patients had shoe size, weight at the last clinic visit, maternal height, posterior sagittal diameter, anterior–posterior diameter of the pelvic inlet and anterior–posterior diameter of the pelvic outlet recorded, respectively (Fig. 1). The indications of CT pelvimetry were as follows: (1) As part of evaluation prior to a trial assisted breech delivery [107 (32.6%)]; (2) in the puerperium, following a primary cesarean operation [150 (45.7%)]; (3) previous cesarean delivery prior to allowing a trial vaginal birth (VBAC) [40 (12.2%)]; (4) freely movable "high head" at term [25 (7.6%)]; and (5) the remaining 5 (1.5%) were for unstable lie; congenital scoliosis; previous; pelvic fracture, shoulder dystocia, and difficult vaginal delivery. The indication of pelvimetry in one patient could not be ascertained from the case records.

Descriptive data from mothers with adequate and inadequate pelvis were compared using the independent *t* tests. A linear, followed by multiple regression analysis was first performed between maternal height, shoe size, weight at the last clinic visit and the various pelvic diameters measured on CT pelvimetry. Before proceeding to the multiple regression models, the potential for co-linearity between the variables was assessed and non-co-linearity existed between the variables. Logistic regression [12, 17] was used to examine the association between pelvic size and maternal height, shoe size, and weight at the last clinic visit. Univariable logistic regression models for each independent variable were examined first. A backward stepwise model building procedure was then used with all three variables in the model with maternal height as the main independent variable to arrive at the set of variables that gave the best model using likelihood ratio tests. To determine the predictive ability of maternal height, shoe size and weight at the last clinic visit, receiver-operating characteristic (ROC) curves (a graph of the sensitivity vs. 1-specificity) were used and the area under the ROC curve (AUC) was determined for each independent variable [8, 22]. A large AUC (closer to 1) indicates the ability of the variable to distinguish between those without, from those with, adequate pelvic size. AUC values close to 0.5 indicate that the ability to distinguish between these two groups is similar to chance. To examine which of the independent variables has a better AUC, *z* tests were used after calculating standard errors of the AUC using the method of Hanley and McNeil [9]. All statistical analyses were performed using the Statistical Package for Social Sciences (SPSS) version 11.5 and statistical significance was assessed using an alpha level of 0.05.

Results

A radiologically inadequate pelvis was seen in 44/327 (13.4%) of the examined women. However, because of missing data only 308 subjects could be included in the logistic regression model out of which 41 (13.3%) had inadequate pelvis (Fig. 1). Demographic data of these patients are presented in Table 1. Patients with inadequate pelvis were significantly shorter, wore smaller shoes and weighed less at the last clinic visit.

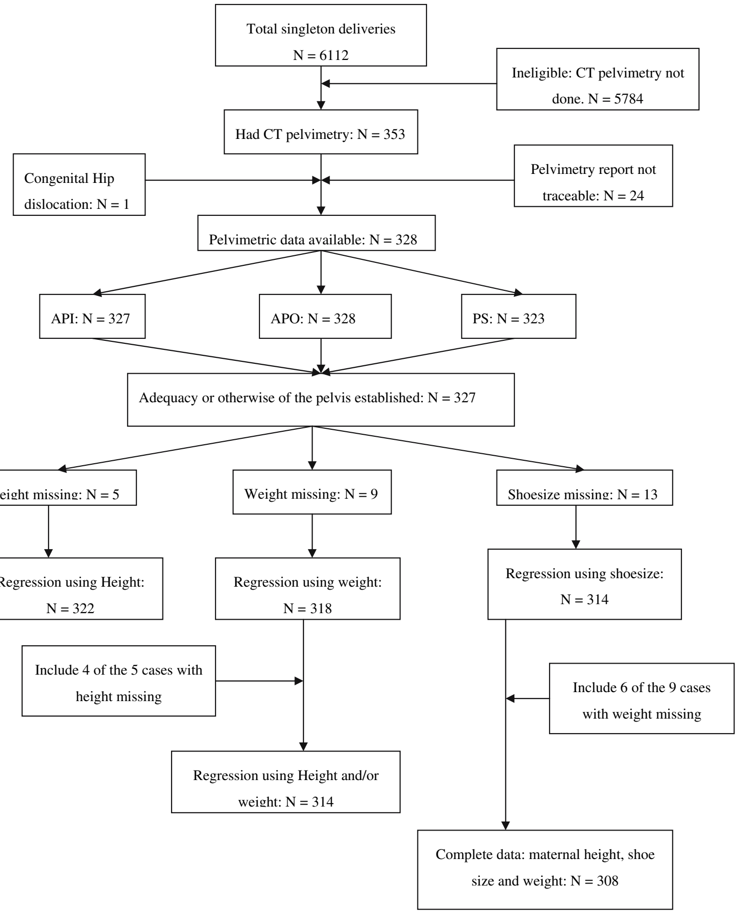

Fig. 1 Patients flow chart *API* Anterior-posterior diameter of the pelvic inlet; *APO* Anterior-posterior diameter of the pelvic outlet; *PS* Posterior sagittal diameter

Table 1 Demographic data of patients who had CT pelvimetry

Demographic variable	Inadequate pelvis		Adequate pelvis		*P*
	Cases	Mean ± SD (95% CI)	Cases	Mean ± SD (95% CI)	
Maternal age (years)	44	26.3 ± 4.8 (24.5–27.5)	283	26.9 ± 4.9 (26.4–27.6)	NS
Maternal height (cm)	43	156.8 ± 6.3 (154.9–158.7)	279	163.1 ± 6.6 (162.4–163.9)	<0.0001
Shoe size (English)	41	4.5 ± 1.3 (4.1–4.9)	273	5.4 ± 1.2 (5.3–5.6)	<0.0001
Maternal weight (kg)	42	71.6 ± 11.8 (68.0–75.3)	276	78.3 ± 13.5 (76.7–79.9)	0.003
Delivery gestation (weeks)	43	38.9 ± 2.0 (38.6–39.7)	281	39.4 ± 1.5 (39.3–39.6)	NS

SD Standard deviation, *CI* Confidence intervals

A linear regression analysis (data not shown) showed that all independent variables predict the various pelvic diameters measured on CT pelvimetry. However, multiple linear regression analysis showed that maternal height [regression coefficient (RC) 0.06, (CI 0.04–0.08), and adjusted R^2 of 23.3%, $P < 0.0001$] but not shoe size [RC 0.07, (CI −0.04 to 0.18), $P = 0.20$] or weight at the last clinic visit [RC 0.01, (CI −0.003 to 0.013), $P = 0.24$] is predictive of anterior–posterior diameter of the pelvic inlet. Maternal height [RC 0.03, (CI 0.01–0.05) and adjusted R^2 of 9.3%, $P = 0.018$] and weight at the last clinic visit [RC 0.02, (CI 0.004–0.024) and adjusted R^2 of 9.3 %, $P = 0.006$] but not shoe size [RC 0.04, (CI −0.09 to 0.17), $P = 0.54$] are predictive of anterior–posterior diameter of the pelvic outlet. Maternal height, shoe size and maternal weight at the last clinic visit did not predict the posterior sagittal diameter. Table 2 gives the univariable and multivariable logistic regression models and the AUC for the ROC curves. Figure 2 shows the ROC curves for independent variables individually and combined. Maternal height was not significantly better (AUC = 0.768) than shoe size (AUC = 0.686, $P = 0.163$ for the difference in the AUCs) and weight at the last clinic visit (AUC = 0.655, $P = 0.057$ for the difference in the AUCs) in determining pelvic

Table 2 Results of univariable and backward stepwise multivariable logistic regression models to assess the ability of patient's height, shoe size and weight at last clinic visit to predict adequate pelvic size using ct pelvimetry as gold standard

Variables	Univariable analysis					Multivariable analysis (height + shoe size + weight)				
	Predictor	Unadjusted OR (95% CI)	*P*	AUC	SE	Predictor	Adjusted OR (95% CI)	*P*	AUC	SE
Height (cm)	1.16	1.09–1.22	<0.0001	0.768	0.040	1.12	1.039–1.196	0.002		
Shoe Size	1.87	1.40–2.51	<0.0001	0.686	0.043	1.25	0.842–1.843	0.271	0.769	0.038
Weight (kg)	1.05	1.02–1.08	0.0031	0.655	0.044	1.01	0.977–1.041	0.614		
Last clinic visit										

OR odds ratio, *SE* standard error, *CI* confidence interval, *AUC* area under the ROC curve

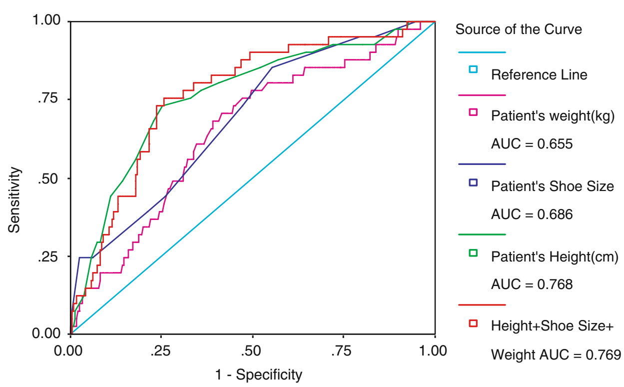

Fig. 2 Area under receiver operating characteristic (ROC) curves between pelvic inadequacy and predictor variables. Area under receiver operating characteristic curves between pelvic inadequacy and maternal height (AUC 0.768, SE 0.040, CI 0.689–0.846, $P < 0.0001$), shoe size (AUC 0.686, SE 0.043 CI 0.603–0.770, $P < 0.0001$) and weight at term (AUC 0.655, SE 0.044, CI 0.569–0.741, $P = 0.002$) and the three predictor variables combined (AUC 0.769, SE 0.038, CI 0.693–0.844, $P < 0.0001$)

adequacy. The backward stepwise modeling building process resulted in the univariable model for maternal height (OR 1.15, CI 1.088–1.218, $P < 0.0001$). The change in the AUC for each of the models (the full model with maternal height, shoe size and weight at the last clinic visit, AUC = 0.769; model with maternal height and shoe size, AUC = 0.767; model with maternal height and weight at the last clinic visit, AUC = 0.766; model with just maternal height, AUC = 0.0.768) was not significantly different. The cutoff point, the point on the ROC curve which maximizes the sensitivity (Se), specificity (Sp), and false positive for maternal height which best discriminates between those without and with adequate pelvic size was 160 cm (Se = 0.767, Sp = 0.660, false positive = 0.341) which was found by determining the point that had the greatest perpendicular distance from the line of chance. Similarly, the cutoff point for maternal height of 152 cm gave sensitivity, specificity, and false-positive values of 0.279, 0.935 and 0.065, respectively, for detecting inadequate pelvis.

Discussion

Our study showed that maternal height, shoe size and weight at the last clinic visit are not useful for the identification of women with inadequate pelveses as these anthropometric measurements are only slightly better than flipping a coin in predicting adequate pelvic size. Kennedy and Greenwald [10] and Frame et al. [7] suggested that women with short stature (<1.52 cm or 60 in.) and those with small shoe size (<4.5) respectively are likely to have their labor complicated by cephalopelvic disproportion or arrest of dilatation or descent hence, by inference, more likely to have an inadequate pelvis. This assertion has not hitherto been properly evaluated. Our study suggests that while there is a good correlation between maternal height, shoe size, and weight at the last clinic visit, and pelvic dimensions, their sensitivity and specificity are too low to be of clinical value in determining pelvic adequacy.

In pregnant women, maternal height is routinely recorded in obstetric records since early studies showed a relationship between maternal height, pelvic dimensions and the outcome of pregnancy [1, 3, 26]. Other studies have looked at the association between maternal height [16, 19], shoe size [10, 14] or both [4, 7, 15, 25] and pelvic size, but all used mode of delivery as a surrogate to determine pelvic adequacy. Frame et al. [7] reviewed 351 women in whom maternal height and shoe size were recorded but only 19 of these had X-ray pelvimetry. However, mode of delivery alone cannot determine pelvic size given that many women who require cesarean operation for "failure to progress" deliver larger infants vaginally in subsequent pregnancies [21].

The strength of our study lies in the fact that all the patients analyzed had erect lateral CT pelvimetry. Although significant correlation exists between pelvic diameters and independent variables in this study, multiple regression analysis showed that shoe size and weight at the last clinic visit were not associated with the various pelvic diameters measured on CT pelvimetry beyond the effects of maternal height. Multivariate logistic regression modeling also showed that when all these variables were included in the model only maternal height predicts pelvic adequacy. In addition, we used an ROC curve [8, 22] to determine whether there are cutoff points of maternal height, shoe size and weight at the last clinic visit above which one can assume that a woman with no congenital pelvic abnormality has an adequate pelvis or below which one can assume an inadequate one. The results of this study showed that maternal height is not better than shoe size and maternal weight at the last clinic visit in predicting adequacy of pelvic size. Although the area under the curve is a useful one-statistic summary of the accuracy of the test variables, the challenge is to select a cutoff that properly balances the needs of sensitivity and specificity. That cutoff point in this study is maternal height of 160 cm. While 76.7% of those with inadequate pelvis are identified correctly at this cutoff, 34.1% of those with adequate pelvis will be labeled incorrectly as having inadequate pelvis. Overall, increasing the sensitivity by taking higher cutoff points is associated with unacceptable false-positive rates. Similarly, using maternal height of 152 cm, 28% of all patients with inadequate pelvis will be identified correctly while 6.5% of those with adequate pelvis will be incorrectly labeled as having inadequate pelvis. Maternal height and shoe size have been previously evaluated and all agree that their predictive values are too low to justify obstetric intervention [4, 10, 14–16, 19, 25]. However, there are those who still believe that they can be used to screen women for delivery at the primary or secondary health care levels [24].

A systematic review that included more than 1,000 women in four trials found that performing X-ray pelvimetry might cause harm without any significant salutary effect on perinatal outcomes [18]. In that review, mothers who had X-ray pelvimetry were 2.17 times (95% CI 1.63–2.88) more likely to undergo cesarean delivery. The fallibility of X-ray pelvimetry is further demonstrated by a study from Scotland [13], which showed that 51 of the 76 women with previous cesarean delivery and a radiologically inadequate pelvis (using similar criteria as in this study) delivered vaginally.

Our study did not seek to evaluate the role of pelvimetry in predicting labor dystocia or cephalopelvic disproportion in part because the diagnosis of the latter is largely subjective in its mild form, as seen in properly managed labor. Maternal height and shoe size [4, 7, 10, 14–16, 19, 25] clinical [6] and X-ray pelvimetry [2] have been found to be insufficiently predictive of dystocia or cephalopelvic disproportion to justify obstetric intervention, either for women with [13] or without [2] previous cesarean delivery. Obstetric populations in the Western World probably have more uniformity of pelvic shape than was the case 60 or 80 years ago when X-ray pelvimetry was commonly performed and when distortion of the pelvis by rickets were common. True cephalopelvic disproportion is now rare in the developed world where most disproportions are due to malposition of the fetal head or ineffective uterine contractions. Given that maternal height, shoe size and weight at the last clinic visit give an unacceptable false positive rate of pelvic inadequacy, obstetricians should not use these measures to foreclose trials of labor.

The limitations of this study are primarily a result of the dates the data were collected—between 1990 and 1991. However, the age of the data does not diminish their reliability or importance. It may also be argued that CT pelvimetry was performed in a narrowly defined group of patients without inclusion of patients with uncomplicated pregnancies. These may have introduced biases due to selection; hence, our results may not be generalizable to the general population. Nevertheless, the Hippocratic maxim “do no harm” makes it unjustifiable to subject women with uncomplicated pregnancies to CT pelvimetry with the sole aim of ascertaining their pelvic size. Caution should also be exercised in interpreting our data in areas where shoe size measurements differ widely from the British predominantly Caucasian population in York, which has a very low ethnic mix. Nevertheless, the results of this study suggest that the predictive values of maternal height and shoe size are too low to justify obstetric intervention; therefore, the collection of maternal height and shoe size are probably redundant in terms of management.

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References

1. Baird D (1949) Social factors in obstetrics. Lancet i:1079–1083
2. Barton JJ, Garbaciak JA, Ryan GM (1982) The efficacy of X-ray pelvimetry. Am J Obstet Gynecol 143:304–307
3. Bernard RM (1952) The shape and size of the female pelvis. Edinb Med J 59:1–15
4. Connolly G, Naidoo C, Conroy RM, Byrne P, McKenna P (2003) A new predictor of cephalopelvic disproportion? J Obstet Gynaecol 23:27–29
5. Dobson J, Nelson J (1988) CT pelvimetry: replacing conventional with digital. Radiography 54:18–19
6. Fine EA, Bracken M, Berkowitz RL (1980) An evaluation of the usefulness of x-ray pelvimetry. Comparison of the Thoms’ and modified ball method of of pelvimetry. Am J Obstet Gynecol 137:15–20
7. Frame S, Moore J, Peters A, Hall D (1985) maternal height and shoe size as predictors of pelvic disproportion: an assessment. Br J Obstet Gynaecol 92:1239–1245
8. Hanley JA, McNeil BJ (1982) The meaning and use of the area under a receiver operating (ROC) curve. Radiology 143:29–36
9. Hanley JA, McNeil BJ (1983) A method of comparing the areas under receiver operating characteristic curves derived from the same cases. Radiology 148:839–843
10. Kennedy JL, Greenwald E (1981) Correlation of shoe size and obstetric outcome: an anthropometric study. Am J Obstet Gynecol 140:466–467

11. Joyce DN, Giwa-Osagie F, Stevenson GW (1975) Role of pelvimetry in active management of labour. Br Med J 4:505–507
12. Khan KS, Chien PFW, Dwarakanath LS (1999) Logistic regression models in obstetrics and gynaecology literature. Obstet Gynecol 93:1014–1024
13. Krishnamurthy S, Fairlie F, Cameron AD, Walker JJ, Mackemzie JR (1991) The role of postnatal X-ray pelvimetry after caesarean section in the management of subsequent delivery. Br J Obstet Gynecol 98:716–718
14. Louw GJ, Davison B (1996) Is shoe size a reliable obstetric predictor of cephalopelvic disproportion? S Afr Med J 86(9 Suppl):1206
15. Mahmood TA, Campbell DM, Wilson AW (1988) Maternal height, shoe size, and outcome of labour in white primigravidas: a prospective anthropometric study. BMJ 297:515–517
16. Mahmood TA (1989) Maternal height, birthweight, obstetric conjugate and their influence on the management of parturients with a previous cesarean scar. Acta Obstet Gynecol Scand 68:595–598
17. Norman GR, Streiner DL (1994) Screwups, oddballs, and other vagaries of science. Locating outliers, handling missing data, and transformations. In: Norman GR, Streiner DL (eds) Biostatistics: The bare essentials. Mosby, St. Louis, pp 202–210
18. Pattinson RC (2003) Pelvimetry for fetal cephalic presentations at term (Cochrane review). In: The Cochrane library, Issue 1. Update Software, Oxford
19. Prasad M, Al-Taher H (2002) Maternal height and labour outcome. Obstet Gynecol 22:513–515
20. Russell JGB, Richards B (1971) A review of pelvimetry data. Br J Radiol 76:817–820
21. Seitchik J, Rao VRR (1982) Caesarean delivery in nulliparous women for failed oxytocin-augmented labour: route of delivery in subsequent pregnancy. Am J Obstet Gynecol 143:393–397
22. Swets J (1988) Measuring the accuracy of diagnostic systems. Science 240:1285–1293
23. Thubisi MM, Ebrahim A, Moodley J, Shweni PM (1993) Vaginal delivery after previous caesarean section: is x-ray pelvimetry necessary? Br J Obstet Gynecol 100:421–424
24. Tsu VD (1992) Maternal height and age: risk factors for cephalopelvic disproportion in Zimbabwe. Int J Epidemiol 21:941–946
25. Van Bogaert LJ (1999) The relation between height, foot length, pelvic adequacy and mode of delivery. Eur J Obstet Gynecol Reprod Biol 82:195–199
26. Walker J (1958) Prolonged pregnancy syndrome. Am J Obstet Gynecol 76:1231–1247