Female pelvic shape: Distinct types or nebulous cloud?

Abstract

The objective of this study was to re-evaluate the Caldwell-Moloy (1933) classification of female pelvic shape, which has been traditionally, and still is currently, taught to students of midwifery and medicine. Using modern pelvimetric methodologies and geometric morphometric (GM) analysis techniques, we aim to elucidate whether these classic female pelvic types are an accurate reflection of the real morphometric variation present in the female human pelvis.

GM analysis was carried out on sets of pelvic landmarks from scans of women living in a contemporary Western Australian population. Sixty-four anonymous female multi-detector computer tomography (MDCT) scans were used for most of the study and 51 male scans were also examined for comparison.

Principle component analysis (PCA) found that there was no obvious clustering into the four distinct types of pelvis (gynaecoid, anthropoid, android and platypelloid) in the Caldwell-Moloy classification, but rather an amorphous, cloudy continuum of shape variation.

Until more data is collected to confirm or deny the statistical significance of this shape variation, it is recommended that teachers and authors of midwifery, obstetrics and gynaecological texts be more cautious about continuing to promote the Caldwell-Moloy classification, as our results show no support for the long taught 'four types' of pelvis.

Keywords: Female pelvic shape, Caldwell and Moloy, Geometric morphometric analysis

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For well over 50 years, students of midwifery, obstetrics, gynaecology and related professions have been taught the Caldwell-Moloy classification of the female pelvis. While recognising variation and mixed types, the current e-book of *Mayes' Midwifery* (MacDonald and Magill-Cuerden, 2011), is typical in its frank reporting and use of that system. 'Although there are four recognised pelvic categories (Caldwell et al, 1940: Table 24.1), variations within these categories can occur. Some women may have mixed features, such as a gynaecoid posterior pelvis and android fore-pelvis' (Burden and Simons, 2011: 286). The 10th edition of *Clinical Obstetrics* also gives Caldwell-Maloy classification system similar prominence (Gopalan and Jain, 2005).

The basic 'four types of pelvis' categorisation persists to this day and is evidenced by the fact that it is taught in many universities and colleges globally and regularly cited in university-level midwifery course compulsory texts, such as *Mayes Midwifery* (MacDonald and Magill-Cuerden, 2011) and *Myles' Textbook for Midwives* (Fraser and Cooper, 2009) and referred to in recent studies on female pelvic shape variation (e.g. Hashemi et al, 2010). The four types of pelvis categorisation persists even though the initial simple classification was subsequently extended by Caldwell et al (1940) to include 14 sub-types, and that it has also been criticised, for example, for being overtly racist (Geller and Stockett, 2007).

A recent study of 172 women in a Latvian population reported a cluster analysis of four measured diameters of the pelvis; however, these did not mirror the Caldwell-Moloy (1933) classification. Using SSPS, the researchers found three clusters based on an analysis of two linear measures, the anterio-posterior diameter and lateral diameters (Kolesova and Vetra, 2012). In contrast, the 3-D GM analysis of the population reported in this Western Australia (WA) study found no such clustering.

This WA study is part of a larger project analysing pelvic shape for sex estimation in a forensic context (Franklin et al, 2012a; 2014). These methods were applied to investigate the long standing pelvic classification of Caldwell et al (1940), in order to re-evaluate its biological foundations. The aim of the study was to elucidate whether these classic female pelvic types are an accurate reflection of the real morphometric variation present in the female human pelvis.

What is the basic classification?

The pelvic shape types in the Caldwell–Moloy classification will now be defined. These are more fully described in Caldwell et al (1940).

The four major types are: gynaecoid, android, anthropoid, and platypelloid (*Figure 1*). The gynaecoid (Greek: gyne + eidos = 'woman type') form is the type allocated to the 'normal' female form and has a round or slightly transversally oval shaped pelvic brim. It has a wide sub-pubic arch and the sacrum is inclined posteriorly. The android (Greek: andros + eidos = 'man type') form has the 'classic' male, 'pear shaped' brim with the widest transverse diameter at the brim, closer to the sacrum than the pubis. The sub-pubic arch is narrow, the sacrum is inclined anteriorly and the cavity is funnel shaped with prominent ischial

Table 1. Caldwell-Moloy subtypes, comments and numbering system

		Posterior segment type			
		Gynaecoid	**Anthropoid**	**Android**	**Platypelloid**
Anterior segment type	**Gynaecoid**	True gynaecoid (4, normal female pelvis)	Anthropoid–gynaecoid (2)	Android–gynaecoid (10)	Flat–gynaecoid (13)
	Anthropoid	Gynaecoid-anthropoid (5)	True anthropoid (1, transversally contracted type)	Android-anthropoid (9)	Flat–anthropoid (not included)
	Android	Gynaecoid-android (6, gynaecoid with narrow front pelvis)	Anthropoid-android (3, anthropoid with narrow fore pelvis)	True android (8, masculine type, funnel type)	Flat–android (14)
	Platypelloid	Gynaecoid-flat (7)	Anthropoid-flat (not included)	Android-flat (11)	True platypelloid (12)

From: Caldwell et al (1940)

spines. Anthropoid, despite its name (Greek: anthropos = 'human'), denotes a more ape-like shape, where the anterior-posterior (AP) diameter at the brim is significantly larger than the lateral, giving a long narrow oval shape. Finally, the Platypelloid (Greek: platys + eidos = 'flat type') form is where the lateral diameter at the brim is significantly larger than the AP, giving a flat or transversally oval form (Caldwell et al, 1940; Burden and Simons, 2011).

Caldwell and Moloy (1938) found that the gynaecoid form was the most common among women, with around 42% of the populations studied having this type. In their study, 'White' and 'African American' females were published separately—in *Figure 1*, they are combined.

How was the basic classification enhanced?

Caldwell and Moloy (1938) and Caldwell et al (1940) extended their classification. In addition to the four 'classic' or 'pure' types, it was decided that combinations ('mixed' types) were not only possible, but actually more likely. They describe 'departures' where the classic form at the pelvic inlet differs from that below it. For example, a classic gynaecoid laterally oval pelvic brim shape, may be reclassified 'mixed' if they also exhibit a narrow sub-pubic arch, an anteriorly tilted sacrum or narrower sciatic notch (Caldwell et al, 1940). Other 'mixed' types were also reported where the anterior section of the true pelvis differs from the posterior segment. These became the basis for the enhanced classification, where the parent type of the posterior segment is combined with the parent type of the anterior—e.g. a pelvis with a male-like sacrum inclination and diminished sciatic notch but with a wide sub-pubic angle would be termed 'android-gynaecoid' (*Table 1*).

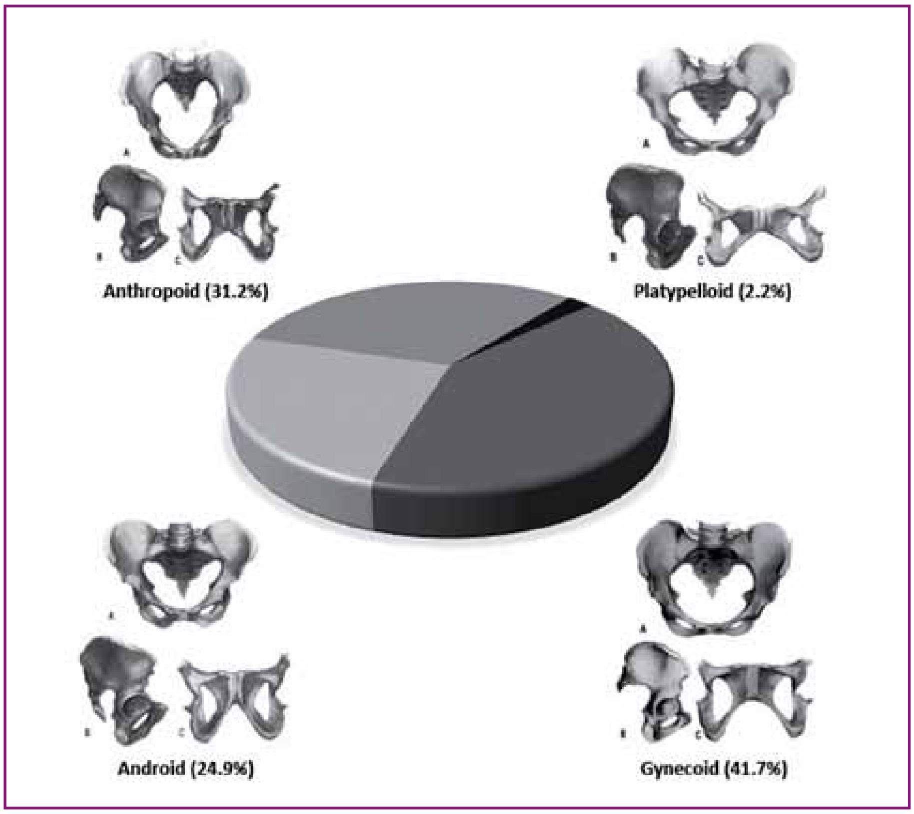

Figure 1. The basic Caldwell-Moloy classification and reported prevalence (adapted from Caldwell et al, 1940, data from US population. Black and White populations were reported originally, combined here)

Following this, each anterior type could theoretically be combined with any of the four posterior types, yielding 16 possible types and, assuming the same number of permutations could exist for both the inferior and posterior aspects of the pelvis, there could be as many as 256 subtypes in total.

However, Caldwell et al (1940) chose not to include a distinction between inferior and superior aspects in their subtype classification and decided that it was impossible for the anthropoid segment to combine with a platypelloid one in either of the two combinations (Caldwell et al, 1940), resulting in just 14 subtypes as outlined in *Table 1*.

It was proposed that 'borderline types' of pelvis can be described by using these combinations (Caldwell and Moloy, 1938), but there appears to be little consideration that there may be a smooth continuum of shapes from one type to the next, within each segment type itself.

Sixty years of the Caldwell-Moloy classification in midwifery, obstetrics and gynaecology

Exactly when the Caldwell-Moloy classification of the female pelvis became widely adopted as a standard in the teaching of midwifery and medicine is open to debate, but there seems little doubt that by the 1950s it was already well established. Medical and midwifery textbooks in the 1970s and 1980s continued to categorise pelves in that way (Beischer and Mackay, 1979; Bennett et al, 1989) and suggested that the type of pelvis determined the passage of the fetus during birth: 'These differences in pelvic shape are of more than radiological interest, since they determine, in large measure, the mechanism which is adopted by the fetus in passing through the birth canal.' (Beischer and Mackay 1979: 23). This general assumption associated different types of pelves with different mechanisms of labour because of the differences within the true pelvis. This is important because as Burden and Simons (2011: 286), in MacDonald and Magill-Cuerden point out, 'the most important factor is the true pelvic space available for the fetus to descend and emerge from the pelvis during labour.'

The ideal pelvis for childbirth allows the fetus to engage in the transverse position due to the wide transverse diameter at the brim, rotate mid-cavity at the level of the pelvic floor as this plane of the pelvis is circular and then birth in an occipito-anterior position taking advantage of the long anterio-posterior diameter at the pelvic outlet. Pelves of different shapes are considered to affect the labour in different ways. The android pelvis, because of having more space posteriorly at the brim, is considered to increase the likelihood of an occipito-posterior engagement of the head (Burden and Simons, 2011). The fetus may remain posterior through labour or may become impinged on the prominent diameter between the ischial spines ischial spines during the rotation mid-cavity, causing a deep transverse arrest necessitating birth by rotational forceps or caesarean section. The anthropoid pelvis, with its long anterio-posterior oval shaped brim causes the fetus to engage in either the occipito-anterior or occipito-posterior position equally and the flat sides and large anterior posterior diameter to the outlet allows the fetus to descend without rotation; therefore, the baby may be born in a persistent occipito-posterior position (Burden and Simons, 2011). A platypelloid pelvis would encourage engagement in the occipito-lateral position and is more likely to cause asynclitism in labour as one parietal bone enters the pelvis before the other. The android and platypelloid pelvis types are most likely to cause obstruction (Burden and Simons, 2011).

The clinical rationale for categorising pelves was to be able to predict these various mechanisms of labour and the possibility of cephalopelvic disproportion (Caldwell and Moloy, 1933). However, over time, it became apparent that theoretical pelvic shapes do not necessarily determine labour outcomes. It is virtually impossible to predict birth outcomes before labour even starts (Hanzal et al, 1993; Spörri et al, 2002). The need for pelvic categorisation was therefore questioned from a practical obstetric point of view, yet the classification is still described in current textbooks for midwives and obstetricians (Gopalan, 2005; Fraser and Cooper, 2009; MacDonald and Magill-Cuerden, 2011).

Potential racist criticisms of the Caldwell-Moloy classification

Caldwell and Moloy wrote many statements that can potentially be perceived as racist today. For example, the populations that the authors linked more closely to the 'anthropoid' pelvis are characterised as 'primitive races' (Caldwell and Moloy, 1938: 5). Since then a number of fossil pelves (e.g. Australopithecus afarensis; Tague and Lovejoy, 1986) have been found, attributed to putative hominin ancestors, which are distinctly platypelloid in shape, a form that Caldwell and Moloy described as ultra-human and not intermediate between humans and the great apes in shape (Australopithecus africanus; Zuckerman et al, 1973).

New morphological approaches

Although some of the X-ray imaging methods used by Caldwell and Moloy to identify the shapes of female pelves were innovative in their time, the original basis of the 'four type' classification was simply observational. Various measurements taken of ratios and angles of selected pelvic landmarks were used to help classify pelves, but the decision was always, in the end, one based on a subjective assessment.

More sophisticated techniques of shape analysis are available today. For example, landmark-based GM methods have been successfully employed for several years in various studies in physical anthropology, palaeoanthropology and forensic science, and have been shown to elucidate novel morphometric features not readily described using simple linear measurements (Franklin et al, 2014).

Rather than simply using 'traditional' ratios (e.g. lateral pelvic diameter divided by anterio-posterio pelvic diameter) and angles (e.g. sub-pubic) to attempt to classify pelves, large groups of homologous landmarks can be captured as discrete 3-D (x, y, z) co-ordinates, stored, rendered graphically and then statistically analysed, all using sophisticated modern computer software.

Baab et al (2012) summarise these GM techniques and some of their recent uses in physical anthropology. They describe how, in theory, GM methods mathematically describe the whole shape of the specimens of interest so that they may be evaluated objectively and statistically. Their paper focuses on studies of the human skull, but the greater shape variation in the human pelvis (especially between the sexes) supports that these techniques should yield potentially even more valuable and clinically useful insights, as we hope to show here.

The uncertainty surrounding the Caldwell and Moloy classification provides an excellent opportunity for the application of these methods. In particular, the true pelvis, including features of the pelvic brim, such as the sacral promontory; mid-cavity, such as the subpubic arch and outlet, such as the ischial spines, can be statistically quantified using a relatively novel technique in GM—semi-landmarks. Even the shape and curvature of featureless regions of bone can be traced using homologous sets of 3-D landmarks.

Following in the footsteps of Caldwell and Moloy's pioneering research, this study is also based on the analysis of a living population of females (and, for comparison, some males) taken from a contemporary WA population, rather than temporally and geographically removed skeletal collections. Rather than using the fixed, two-dimensional X-ray images that were taken by Caldwell et al (1940) in postnatal women, the present study analyses dynamic, 3-D images generated from computer tomographic (CT) scans using the image rendering program, Osirix™.

Hypothesis

If the Caldwell and Moloy Classification is morphologically accurate, there should be discernible clustering patterns visible when 3-D GM data of female pelves are statistically analysed in Morphologika. Specifically, there should be four significant groups corresponding to their four 'types' of pelvis when individual morphs are plotted against the major principal components.

Methods:

Computer tomographic scans as a source for pelvimetric population data

The Centre for Forensic Science at the University of Western Australia (UWA) has been developing techniques for acquiring 3-D landmarks in CT scanned images. These techniques have been applied in studies of various parts of skeletal anatomy and results have been verified against traditional measurement methods (Franklin et al, 2012a; 2012b; 2014).

CT scans are specifically well-suited to skeletal biological research as the post-cranial skeleton can be filtered out from the rest of the scanned tissue with a high degree of resolution. The scans assessed typically have a 1 mm slice thickness, the visualisation of the regional skeletal anatomy is therefore performed at a much higher level than that of the X-rays used by Caldwell et al (1940).

Sample demographics

This study quantifies measurements from CT scans from 64 women currently residing in WA. A sample of individuals was randomly selected from the WA Department of Health (DH) Picture Archiving and Communication System (PACS) database, and consists of adult patients presenting at various hospitals during 2010–2011. The scans were anonymous when received by the authors with only sex and age data retained. The mean age of the males was 47 years (range 22–63), and 44 (range 18–63) for the females. Sample demographics are described in *Table 2*. While undoubtedly comprising various ethnic backgrounds characterised in the general WA population, the sample is predominantly Caucasian which typified the WA population. Only individuals without obvious congenital or acquired pelvic pathology were included.

Ethical approval

Ethical research approval was granted by the Human Research Ethics Committee of the University of Western Australia (RA/4/1/4362).

Landmark schema

Pelvic shapes were recorded using a defined set of 77 landmarks designed to represent homologous bony features, these are used to generate semi-landmarks that trace a further 150 relative smooth and featureless curves and surfaces, making 228 landmarks in total. In addition, to point type landmarks, taken from relatively easily-identifiable

Table 2. Demographics of participants		
Age range	**Females**	**Males**
18–20	2	0
21–30	7	6
31–40	10	7
41–50	24	19
51–60	18	17
61–70	3	2
Total	**64**	**51**

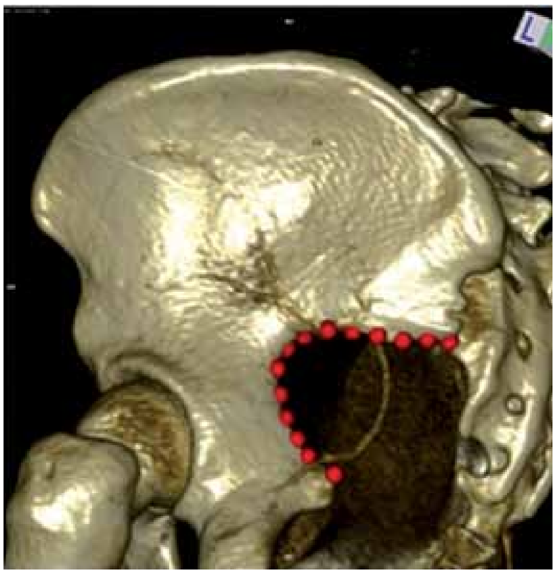

Figure 2. Screen shot demonstrating semi-landmark placement in Osirix™

points on the pelvis, the shape of a series of significant curvatures of bone, that are relatively featureless, were also captured for analysis via semi-landmarks.

Each semi-landmark set is defined by a point type landmark to demarcate its start and end point as well as the number of landmarks to be generated along the curvature of bone (*Figure 2*). The semi-landmark co-ordinates were generated by an in-house developed database application, MorphDb.

Osirix™ data capture

Data are collected using the open source DICOM (digital imaging and communications in medicine) software package, Osirix™. The software allows the DICOM file data to be filtered by the density of the voxels (3-D pixels) so that only skeletal structures are visible. The objects are thus rendered as 3-D objects that can be rotated and zoomed in or out. Osirix™ allows the placement of landmarks onto the surface of the rendered image, each of which captures the (x, y, z) co-ordinates of the point. These data are then downloaded and processed in a custom-built database package.

3-D GM analysis with Morphologika

Prior to analysis, the landmarks obtained for each specimen needed to be put into a common co-ordinate system where all morph entities were standardised for size and orientation leaving relative variation purely to shape. Then, a PCA was performed, which determines the key principal components, which discriminate the pelves on shape. Morphologika can then plot the individual morphs against two axes, representing two principal components, at a time. Using this method, most of the shape variation in a set of morphs can be visualised and explored. Morphologika displays the landmarks with, or without, a wireframe to link them (*Figure 3*) allowing them to be rotated and the shape variation to be explored against the principal components being analysed.

Results:

Anterio-posterior/lateral diameter ratio cluster analysis

Following the Kolesova and Vetra (2012) study, which found some clustering in their analysis of anterio-posterior/lateral diameter ratios, these measures and their ratios were extracted from this data set for analysis. Generally, the range of ratios ran smoothly from rather platypelloid (anterio-posterior 83.4% of lateral) to rather anthropoid (anterio-posterior 113% of lateral) in 63 of the 64 individuals. With the exception of one woman that was markedly anthropoid at anterio-posterior 146% of lateral, there were no significant clusters of data.

Female only

The PCA of the 64 female pelves revealed that 13% of the variation was accounted for by the first principal component, 47% by the first six. No obvious clustering patterns were visible in any of the 15 pairwise comparisons of the top four principal components (*Figures 4 and 5*).

Subjective assessment of female-only data

From the female-only data there is no obvious clustering of points into four distinct shape types so it was decided to add to the dataset one of the four 'type specimen' in the Caldwell-Moloy specification—the android (or 'male') type. According to the traditional classification, approximately 25% of female pelves should fall into this category.

Males included

The sample was then analysed with male pelves

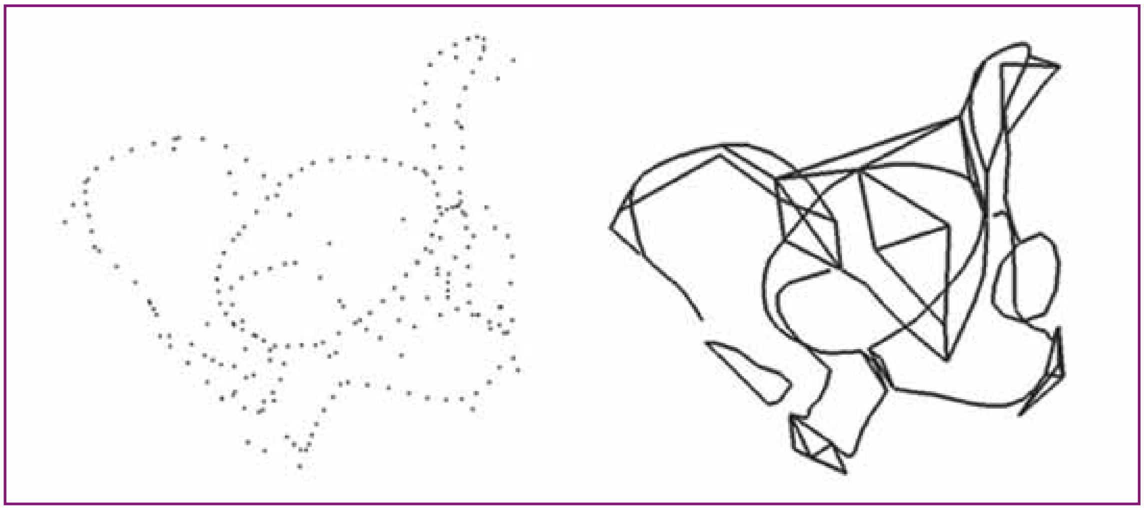

Figure 3. Pelvis using semi-landmarks rendered without (and with) a wireframe

included. If the Caldwell-Moloy android type of female pelvis was found among this population, one would expect to see some overlap with, or at least a distinct grouping close to, the male distribution.

As shown in *Figure 6*, female and male and pelvis shapes do not overlap at all when compared by the most discriminatory principle component—PC1, and there is no distinct group of females that appears in close proximity to the male group.

Discussion

Historically, students of midwifery and medicine have been taught that women will have either a gynaecoid, android, anthropoid or platypelloid pelvis. The results of this WA study did not reflect the current taught concept that there are four distinct type of pelvis. Rather than falling into specific categories, the pelves formed a nebulous cloud of variation. Furthermore, the concept of 25% of women having an android, or male shaped, pelvis was refuted. In this study, the analysis of both male and female pelves clearly demonstrated two distinct groups with no overlap, suggesting that the android shape occurs in women very rarely, if at all.

The limitation of this study was that the sample size was small and geographically specific. A greatly expanded study, in terms of number and geographical origin, would be required to address this issue.

Conclusion

This study is preliminary in nature but appears to provide sufficient evidence to cast doubts on the Caldwell et al classification. These findings suggest that it would be worthwhile to reconsider the traditional teaching of midwifery, medical and related professions that there are four distinct types of female pelvis and, instead, encourage

Table 3. Principal components analysis of female pelves

Principal component (PC)	Individual	Cumulative
PC-1	0.129	0.129
PC-2	0.104	0.232
PC-3	0.083	0.315
PC-4	0.057	0.372
PC-5	0.054	0.426
PC-6	0.046	0.471

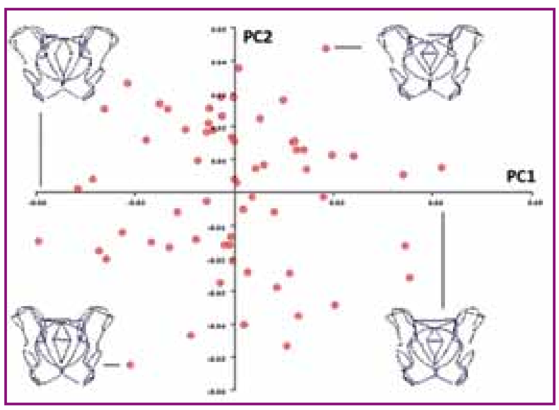

Figure 4. PC-1 x PC-2 (Female only)
(Pelvic images give indication of the shape differences at the extremes of the principle components)

the concept that the shape variation is simply characterised by a cloudy continuum.

The key argument of this paper is to question the traditional midwifery teaching that a woman's pelvis can be pigeon-holed, by its shape, into one of four categories. Complex physical traits, such as body height and the morphology of major skeletal structures, are doubtless under the genetic control of several alleles and many environmental and

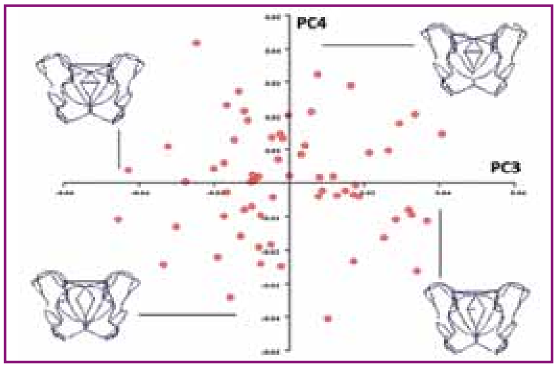

Figure 5. PC-3 x PC-4 (Female only)
(Pelvic images give indication of the shape differences at the extremes of the principle components)

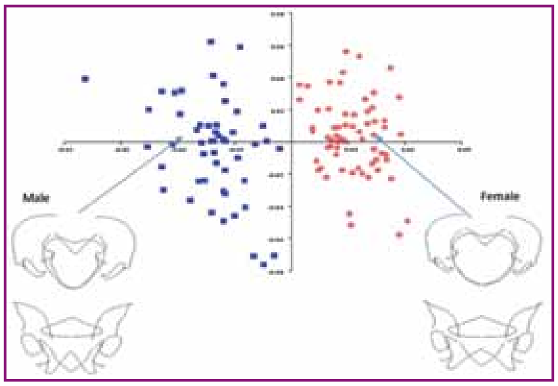

Figure 6. PC-1 v PC-2 male and female. No significant group of females overlap with, or even cluster close to the male as one would predict if there was an 'android' type of female pelvis

epigenetic factors. This type of control predicts that any statistical analysis of related measures will follow a smooth continuum in a normal distribution as seen, for example, with body height. Our results support the expectation that such a smooth distribution of shapes exist in the pelvis.

Rather than trying to determine which distinct type of pelvis a woman has, we argue that it is more helpful to simply have an awareness that pelvic shape has many components that may affect childbirth, each of which can vary smoothly. Certain phenomena, such as a high head at term or deep transverse arrest, could be due to a more exaggerated oval shaped brim or more prominent ischial spines; to attempt to explain such events by categorising the pelvis is not necessary and will not affect the management of labour. BJM

Key points

- Women's pelves may not be definable as one of the four types as described by Caldwell and Moloy
- The male pelvis (android) is distinct from the female pelvis

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