The movements of the maternal pelvis — a review

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Introduction and background

This piece of work was inspired by the work of New Zealand midwife, Jean Sutton, whose 1996 pioneering article on the 'engineering miracle' of birth captivated my interest. Sutton's idea that a mother's pelvis expands to accommodate her baby during labour, made perfect sense to me: Why was it that women would often lift their buttocks off the bed as they pushed their babies out? Sutton's (1996) article offered a credible explanation for this, describing how a reflex action, triggered as the infant descends into the pelvis, causes the 'Rhombus of Michaelis' (an area comprising of the coccyx, sacrum and lower lumbar vertebrae) to move backwards. This action then facilitates normal physiological birth due to the expanded pelvic cavity.

However, whilst Jean's ideas were extremely plausible and persuasive, she offered no tangible supporting evidence for this. Even when pressed for background information during one of her popular 'optimal fetal positioning' workshops, Jean replied (in typical Antipdoean style) '*Ah, how do you **un**bake a fruit-cake?*' Here I assumed she was highlighting the complexities of the birthing process which she perhaps felt could not be broken down into component parts. Despite my disappointment, I still felt that Jean was instinctively right in her assertions. I also needed a dissertation topic and so I decided to take on the task to search for evidence which would either support or disprove the notion of spontaneous pelvic expansion during labour.

What now follows is an outline of my findings which will hopefully further our understanding of the behaviour of the maternal pelvis during childbirth.

Method: how to 'unbake' a fruit cake...

As I was not able to identify any previous review of the literature in this area, I set very broad search parameters in order not to miss any relevant studies. The usual study design and methodological filters, as well as date limitations, were not applied as I anticipated that very little literature would be uncovered. Therefore, an inclusive and a pluralistic interpretation of evidence was adopted making experimental, non-experimental, expert opinion, historical and experiential evidence acceptable. Electronic searches, citation tracking and several visits to the British Library in London followed.

My intention was to systematically search as broadly and as exhaustively as possible, and in so doing 'unbake' Jean's fruitcake for her…

Findings

All accepted literature was read, analysed and surprisingly (due to quantity) sorted into themes. As I had set no date limitations, interesting historical arguments on the maternal pelvis were revealed. This logically formed the first theme, as it contextualised what transpired to be a centuries old debate regarding the mobility of the maternal pelvis in childbirth. Literature concerning pelvic anatomy and mobility are addressed within the second theme. Key research-based findings regarding pelvic movement in labour are then fully considered in

"Why was it that women would often lift their buttocks off the bed as they pushed their babies out?"

theme four. And, lastly, the possible causes of pelvic expansion during labour are examined in theme five, including Jean Sutton's theory of reflex expansion.

Theme 1

The pelvis moves in labour — or not? Historical views and arguments

Interest in the mobility of the pelvis can be traced back to the time of Hippocrates. The Hippocratic corpus cites the theory of '*disjunctio pelvica*' where a physical separation of the pubic bones occurs during a woman's first labour. Thereafter, a woman's pelvis was thought to remain 'open' (Graham 1950). After Hippocrates, the topic of pelvic expansion during childbirth appears to have been a focus of ongoing, sporadic debate. Within the literature reviews of Duncan (1854), Heyman & Lundqvist (1932) and Lynch (1920) various medical opinions are highlighted, most of which favour that the maternal pelvis is an unyielding ring. Within the field of obstetrics, Mauriceau writing in 1668, is cited by Heyman & Lundqvist (1932), to have thought it was impossible for the pelvis to expand. However, doubts were cast by Paré in1575, the influential French surgeon is quoted in Lynch (1920): '*The pelvis is so small, how can a baby come through so small a space unless the pelvis yields?*'

Expansion via the pubic symphysis or sacrum?

Historically most of the opinions which accept the occurrence of pelvic expansion, appear to be based on a belief in the separation of the pubic symphysis. Weisl (1955) noted that the longevity of this view is likely to have been based on the frequent finding of pubic diastasis in dissected maternal cadavers. This belief is finally discredited in 1932 by Heyman & Lundqvist's (1932) X-ray study of labouring women (considered in Theme 1).

The earliest detailed account, which rejects the notion of symphyseal expansion in labour, comes from Hendrik van Deventer (1716), a Dutch obstetrician. Van Deventer was an anti-forceps practitioner who undertook and taught pelvic manipulation as a technique to facilitate difficult births. His alternative approach to childbirth was unique amidst the background of 18th century forceps experimentation. He writes:

'*The greatest Opening and Enlargement of the Pelvis, to make Way for the Foetus is not to be expected from the separation of the Ossa Pubis, but from the yielding or giving Way of the Os Sacrum, either Total, or towards the Point, or the Os Coccygeus. The straightness of the Upper part of the pelvis, does not so much occasion a difficult birth, as the small space betwixt the seat bones and the os coccygeus… therefore it matters not much, whether the Ossa Pubis are separated or not…. All the bones which are tied together with ligaments, may be disjointed and moved out of their natural place, and in some cases, I have very much relaxed them.*' (van Deventer 1716:18).

Here his belief in the mobility of the posterior wall of the pelvis, via movement from the sacrum and coccyx, is demonstrated. He goes on to make recommendations for practice, where again his belief in sacral mobility is made plain:

'*If the passage, as it often happens, is made too narrow for the infant…, the midwife should thrust back the point of the os sacrum, to make way for the Infant as it goes out, which may be done better by the Midwife's Hand, than by the Head of the Infant…. the Os Sacrum, is commonly the greatest hindrance to the infant's going out.*' (van Deventer 1716:126).

The practice of pushing back the posterior wall of the pelvis became known as *Deventer's manoeuver*, which he successfully taught to obstetricians in London during the 1690s. Unfortunately, despite van Deventer's views and teachings, his approach waned and the notion that the maternal pelvis was a static structure prevailed, as evidenced within the question posed by Roederer in 1773 (cited by Lynch 1920): '*Will not the foetal head give sooner than the pelvis?*'

The final pre-20th century opinion on pelvic mobility was provided by Duncan (1854). He, like van Deventer, describes a movement coming from the posterior pelvis during birth. Duncan (1854) observed that, during the second stage of labour, women tended to elevate their symphysis pubis which served to enlarge the pelvic outlet due to an accompanying rotation of the sacrum. He describes this rotational or 'nodding' movement of the sacrum as 'nutation' — a term which does not reemerge until the anatomical research of Weisl (1955) considered later.

The final evidence which demonstrates the longevity of the belief in symphyseal separation as the basis of pelvic mobility, is demonstrated within the studies of Heyman & Lundqvist (1932) and Lynch (1920). Within their work the then new technique of X-ray imaging is used and the first

research-based evidence which **discredits** the belief in symphyseal expansion is presented.

It should be acknowledged that in all of the reviewed X-ray studies there are ethical concerns regarding the mothers comfort and the irradiation of the mother and infant. However, the consequences of X-ray exposure were not known at that time, and so any harm caused by these early studies was arguably inadvertent.

Lynch's (1920) X-ray study highlights cases where women demonstrate a degree of sacroiliac expansion — one of which was taken during labour. He states that a widening of the sacroiliac joint spaces is a constant phenomenon in his work and provides us with the first visual evidence of possible sacral involvement in labour.

Heyman & Lundqvist (1932) measured the symphyseal gap in a group of 8 women whom they X-rayed throughout labour. As no differences in the widths of the symphyseal gaps were found, it was concluded that no pelvic expansion takes place during labour. And again, as in Lynch's (1920) study, they indicate that there may be some sacroiliac involvement during labour.

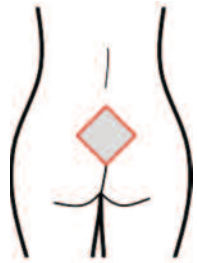
Despite both of these studies suggesting the possibility of posterior pelvic involvement via the sacroiliac joints, this area does not appear to be specifically examined in a research context until the work of Borell & Fernström (1957), considered later.

Theme 2

The anatomy and biomechanics of the posterior pelvis: the female pelvis — better by design?

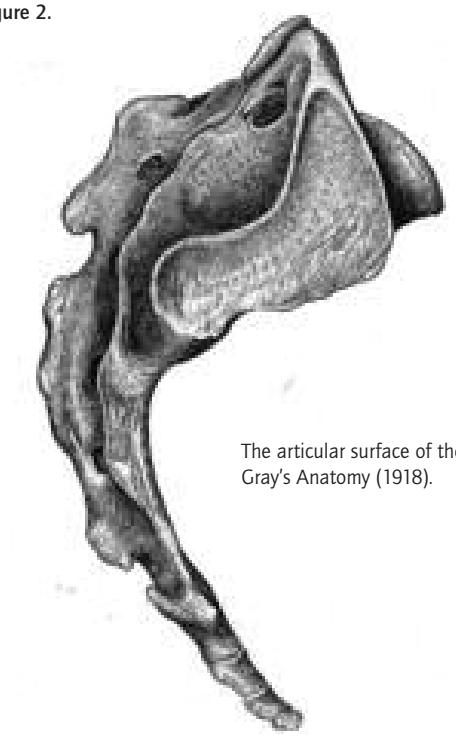
Sutton (2001) describes the posterior pelvis as the 'Rhombus of Michaelis'. This section of the lower back is likely to be named after professor Gustav Michaelis (1798–1848), a German obstetrician and professor of anatomy (Morton 1970) (See Figure 1).

Figure 1.



The Rhombus of Michaelis: a diamond-shaped area in which the upper point corresponds approximately to the 5th lumbar vertebra and the lower point equates to the coccyx.

Figure 2.



The articular surface of the SIJ. Gray's Anatomy (1918).

Sacroiliac joint anatomy

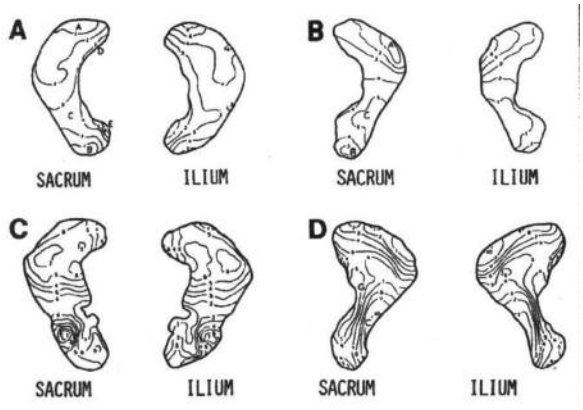
Key to posterior pelvic movement is the sacroiliac joint (SIJ). Within the literature there is widespread agreement that the SIJ is complex and not fully understood (Beal 1982, Walker 1992, McGrath 2004). It is however formed at the articulation of the large innominate bones and the sacrum and is described as being partly synovial and partly a syndesmosis (Drake *et al* 2005). The joint space is described as being 'L' or 'V' shaped' (see Figure 2) with the long arm pointing caudally and the short arm cranially (Beal 1982).

The contouring of the SIJ surface area was demonstrated in Weisl's (1954) early cartographic study of 62 cadaveric specimens. Here, Weisl found that the joint surface was smooth and flat in fetal samples, and that the ageing process increased the number of surface elevations and ridges, which promoted interlocking and stability (see Figure 3).

The increased number of undulations and ridges shown in the male SIJ (see Figure 3C) highlights the relative difference in morphology between the sexes and points to an increased potential for movement in the female joint.

Weisl's (1954) observations have been corroborated by the findings of later anatomical studies, including Bowen & Cassidy (1981), Vogler *et al* (1984) and Vleeming *et al* (1990). There also appears to be a general consensus

Figure 3.



Weisl's (1954) cartographic records showing the increase in frequency and proximity of the contour lines within the SIJ between birth and later life.

A: Full-term fetus; **B**: 20-year old woman; **C**: 45-year old man; **D**: 63-year old man

that increasing unevenness on the surfaces of the SIJ are normal and age-related, and that ankylosis (fusion) and surface irregularities start to appear after the age of 30 (Beal 1982, Walker 1992, McGrath 2004). This is an important point given the advancing average age of childbearing women in western society.

Sacroiliac joint motion

During the course of my searches, citation tracking led me to biomechanical-based research which I had not seen referenced anywhere in midwifery or obstetric literature. These studies provide us with strong evidence that 'the Rhombus' can rise during labour.

The earliest study that specifically looked at SIJ motion was undertaken by Weisl (1955). Here individuals were X-rayed using a pelvic support in various positions. Twenty-six of the individuals were postnatal women who had given birth within the preceding four to ten days days. Weisl (1955) identified two movements of the sacrum: rotation and translation, as well as variable axes of movement. Perhaps not unexpectedly, the greatest degree of sacral movement was consistently found in the group of postnatal women.

The results of Weisl's (1955) research have since been corroborated by several studies using more modern techniques including: *in vitro* SIJ loading (Miller *et al* 1987); and high precision stereophotogrammetry of tantalum (steel) balls embedded into the sacrum and innominate bones (Egund *et al* 1978, Sturesson *et al* 1989, Jacob & Kissling 1995).

A summary of the results of these studies reveal that the motion of the SIJs and sacrum is consistently very small and involves the simultaneous combination of the following movements:

- **Nutation:** This is the forward 'nodding' action of the sacrum. The greatest degree of sacral movement occurs in this action (Figure 4). The range of motion has been identified as being between one and four degrees (Egund *et al* 1978, Sturesson *et al* 1989, Jacob & Kissling 1995). Both Jacob & Kissling (1995) and Sturesson *et al* (1989) describe nutation occurring predominately about the X-axis (Figure 5). The opposite action of nutation, where the sacrum extends is described by Kapandji (1974) as 'counter-nutation'.
- **Translation:** This is not a rotating motion, but a linear displacement (also referred to as gliding) in an anteroposterior plane. Average values of 2.0mm (Egund *et al* 1978); 0.73mm (Jacob & Kissling 1995); 1.7mm (Miller *et al* 1987); and 0.08 mm (Sturesson *et al* 1989) have been measured about the Z and Y-axes (Figure 5). According to Walker (1992) sacral translation should be greatest in the young and least in the old, due to increasing SIJ surface irregularities.
- **Lateral rotation:** This is a rotation around the Y-axis (twisting) for which least movement has been found. Based on McGrath's (2004) review, the range has been found to be between zero and 1.5 degrees.

Although the individual movements are individually very small, they do not occur in isolation. Based on Weisl's (1955) results, it appears that sacral movement is a product of the simultaneous combination of all three: nutation, translation and lateral rotation. Sacral movement is more readily understood when considered along with the findings of the next two studies on maternal positioning in theme three.

Theme 3

Pelvic outlet diameter changes — the difference is the position…

I identified two studies that examined pelvic outlet expansion in relation to maternal position, Borell & Fernström (1957) and Michel *et al* (2002). These results provide us with convincing evidence of sacral mobility and demonstrate that pelvic outlet diameters can be affected by positioning alone.

Borell & Fernström (1957) recruited 151 women in part one of their X-ray study (part two will be considered in

Theme four). The women had either: never been pregnant before; had given birth within one year or more; or had given birth within the preceding four days. X-rays were taken with the women in either: Walcher's lithotomy, standing or a 'dorsal recumbent position with knees supported' position. This slightly unusual position was achieved by the women hooking their knees over the arm of the X-ray machine(!). This lifted their buttocks off the X-ray table and so provided a position in which the sacrum is free (it roughly equates to an *inverted* 'all-fours'). Anteroposterior (AP) diameters of the pelvic outlet were then identified on the X-ray films and measured.

In Michel *et al*'s contemporary (2002) study, various pelvic diameters in relation to birthing position were measured using magnetic resonance imaging (MRI). The chosen positions were: supine, squatting and 'hands and knees'. The sample consisted of 35 women, aged 22 to 43. Pregnant women were excluded (as they couldn't fit comfortably into the designated MRI scanner), as were any women who had given birth in the preceding nine months because it was felt that the squatting position would be too uncomfortable for them to hold for the required three minute scan.

Pelvic expansion via sacral nutation (and maybe translation)

Not surprisingly, due to the joint laxity associated with childbearing, the differences in pelvic outlet diameters identified in Borell & Fernström's (1957) study were found to be greater in the women who had birthed within the preceding four days. Here, changes in the AP diameter between positions, were measured at between 10mm and 30mm.

The most significant result for outlet diameter expansion was identified when the women were changed from the 'sacrum fixed' Walcher's position to the 'sacrum free' dorsal recumbent **with knees supported** position. Twenty-one women had much greater differences in outlet diameters (up to 16mm) when changed from Walcher's to dorsal recumbent with knees supported, compared to only three cases demonstrating a greater difference from Walcher's to lithotomy (6mm average). Five women had no changes in outlet diameters between positions. Outlet increases were also found when the women's position was changed to standing, but to a lesser degree than in the dorsal lithotomy with knees supported position.

Figure 4. Nutation of the Sacrum

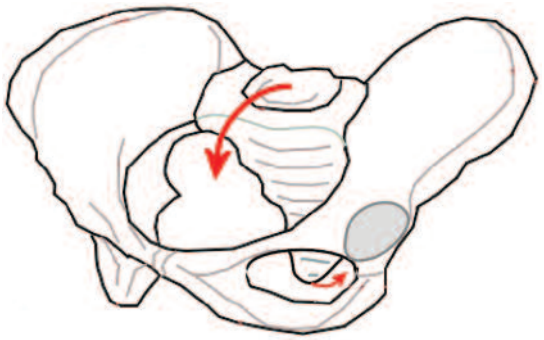
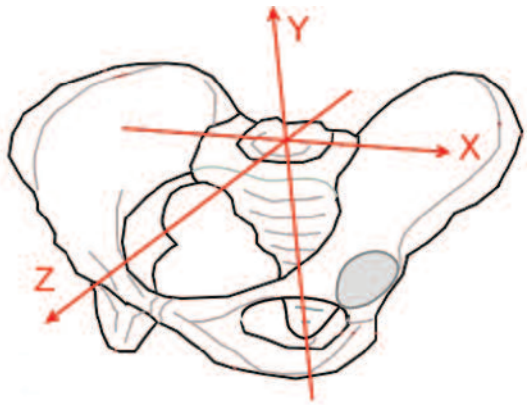


Figure 5. Hypothetical axes of SIJ motion



These results demonstrate that greater pelvic expansion can occur when the sacrum is free to move compared to when a woman is placed in lithotomy. This also helps to dispel the obstetric myth that lithotomy 'optimises outlet diameters'.

Borell & Fernström (1957) also identified AP outlet increases when the women were changed to a standing position, but to a lesser degree than in the dorsal lithotomy with knees supported position. In some women a gliding movement of the sacrum was observed — probably a 'translation' as described in theme two.

Importantly, when comparing data Borell & Fernström (1957) found that the degree of movement around the symphysis pubis is generally greater than the co-existent

"These results demonstrate that greater pelvic expansion can occur when the sacrum is free to move compared to when a woman is placed in lithotomy"

increase in the anteroposterior diameter of the outlet. This demonstrates that the pelvis does not merely rock *en masse* when a woman's position is changed (as it would if it were a fixed structure) but involves some degree of sacral movement.

Borell & Fernström's (1957) findings are largely corroborated by Michel *et al*'s (2002) study. Here, they found that, in positions where the women's sacrum was free to move (ie squatting and 'hands and knees'), AP diameters were greater than in supine positions. Highly significant ($p<0.0001$) increases were identified in the bispinous diameter of the 'hands and knees' and squatting positions when compared with the supine position. The intertuberous diameter was the only measurement found to be greater in squatting positions than in the 'hands and knees' position. However, the effects of squatting lessened with increasing age: the AP diameter of the inlet was found to be greater in younger women ($p=0.05$).

Theme 4

Pelvic movement in labour

Based on the evidence presented so far, it would appear that the female sacrum is capable of movement: nutation and counter-nutation; sacral translation; and lateral rotation. It should however be stressed that, based on Borell & Fernström's (1957) findings, the degree of movement varies between individual women. It also appears that positional changes alone may be sufficient to bring about pelvic expansion. Nonetheless, as the evidence so far is based on data from non-labouring women, we can only infer that the pelvis reacts in the same way during labour.

In part two of their study, Borell & Fernström (1957) examined the course of pelvic movement during the actual labours of 40 women. Anteroposterior and lateral X-rays were taken between contractions at intervals of 0.5 seconds. The women were described as being in a dorsal recumbent position.

Based on their measurements, their study found that during labour a maximum AP expansion of up to 10mm occurs at the pelvic brim. Then, as the head passes through the pelvic outlet, the AP expansion (in most of the women) was measured to be greater than 10mm. In one woman an increase of 20mm was found. Borell & Fernström (1957) also note that very little expansion occurred in 'a few' cases of protracted labour. And, as in part one of the study, occasional gliding movements of the SIJs were observed.

Inter-rater reliability

Arguably, a weakness of Borell & Fernström's (1957) study is that the results are based exclusively on measurements of the AP diameters. However, more than a decade later, Ohlsén (1973) undertook to remeasure Borell & Fernström's (1957) original intrapartum X-rays. His intention was to map the total pattern of maternal pelvic movement by measuring the transverse diameters not calculated during the original study. A significant inclusion was that Ohlsén (1973) recorded the maternal pelvic diameters **in relation to the level of the infant's head during its descent**. He also undertook to measure the inter-sacroiliac distances, ie the space between the two innominate bones in which the sacrum and SIJs lie, in order to try and explain Borell & Fernström's (1957) observations of SIJ *gliding*.

Based on his remeasurements, Ohlsén (1973) found that there was a gradual adaptation of both the AP and transverse pelvic diameters, the sequence of which correlated to the descent of the infant's head. He concluded that pelvic expansion was therefore attributable to the pressure of the infant's head as it negotiates the maternal pelvis.

Gliding?

Ohlsén (1973) calculated an average increase in the inter-sacroiliac distance of 4.2mm however no actual widening of the SIJs was found. This gave rise to a discrepancy between the increased inter-sacroiliac distances without a corresponding widening of the SIJ spaces. Ohlsén (1973) concluded that this equates to a backwards displacement (translation) of the sacrum and so clarifies Borell & Fernström's (1957) findings of occasional 'gliding'.

Overall, Ohlsén (1973) calculated pelvic diameter increases as providing an average outlet area increase of 20% (based on an AP diameter increase of 1–2 cm, and a transverse diameter increase of 0.5cm). Here, it is worth remembering that a relatively large increase in area can be produced from a small increase in diameter.

Theme 5: three theories of pelvic expansion during labour

Overall, I identified three different theories of sacral movement:

"The pelvis should be viewed as a dynamic structure in the birth process, and the facilitation of optimum expansion should be a key consideration of routine labour care"

1. Ohlsén's (1973) theory of fetal head pressure

As previously considered, Ohlsén (1973) mapped the total pattern of pelvic movement during labour (based on Borell & Fernström's X-rays). He concluded that there is a **gradual** adaptation of both the anteroposterior and transverse pelvic diameters during birth which can be attributed to the pressure of the descending infant's head.

2. Russell's (1969) biomechanical theory of sacral displacement

Russell (1969), a radiologist, bases his explanation on a review of pelvimetry data that he collected from pregnant and postnatal women. He explains pelvic expansion as occurring from the action of the abducted femora operating as 'levers': compressing the upper part of the SP and causing a minor separation at the base of the SP, so producing an outward flaring of the innominate bones. The loss of resistance from the innominate bones then allows the sacrum to move backwards and so increases the outlet diameters. Sacral movement is therefore dependent on the downward weight of the trunk and upward thrust of the femora (Russell 1969).

3. Sutton's (1996) theory of reflex expansion of the posterior pelvis

Based on her 40 years of experience in midwifery, Sutton (1996a, 1996b, 2000, 2001) proposes that as the infant descends the maternal pelvis, the back of its neck comes into contact with a nerve plexus, near the junction of the bladder and urethra. This then triggers a backwards movement of the Rhombus of Michaelis of up to 2cm. Sutton (2001) maintains that this is a unique movement which does not arise due to pressure from the descending head.

Conclusion

If the key findings of this review are pieced together then possible explanations for practice can be made — and fruit cakes may be partially unbaked…

Based on the evidence presented, it appears that maternal pelvic diameters expand in relation to fetal descent during labour. The actual movements of the pelvis are likely to involve sacral counter-nutation, produced when the fetus passes the sacral promontory, followed by an action of nutation when the fetus passes the pelvic outlet. For some women, a translatory movement may accompany sacral rotation. Together these equate to a backwards movement of the posterior pelvis or a rising Rhombus of Michaelis. It is likely however, that sacral movement is not possible in all women and this may be due to reduced SIJ mobility.

Regarding the spontaneous enlargement of the pelvis, the evidence suggests that pressure from the descending infant accounts for any expansion seen. It also appears likely that pelvic enlargement may be enhanced if a birthing position is adopted that allows the sacrum to be free. **Further** enlargement of the pelvic diameters during labour may be encouraged by the adoption of squatting or modified squatting positions. In these positions, the transverse diameters of the pelvis are likely to expand further which may help to release the sacrum from between the innominate bones and allow greater movement.

Recommendations:

- The pelvis should be viewed as a dynamic structure in the birth process, and the facilitation of optimum expansion should be a key consideration of routine labour care. The obstetric culture of supine birthing positions for normal childbirth should be challenged in favour of 'sacrum free' birthing positions so that pelvic expansion may be optimised.
- Further research into the behaviour of the pelvis during labour is needed; ideally where pelvic diameters are examined in relation to birthing positions that allow the sacrum to be free. However, the identification of an

ethically acceptable method of medical imaging is likely to prove problematic.

- The reasons for pelvic immobility during labour should be explored with a view to better understand how this may be identified and overcome in order to optimise the likelihood of pelvic expansion and thus normal childbirth.
- Research into the supportive soft tissue of the pelvis, eg muscles, fascia and ligaments, needs to be explored and how this, along with pelvic movements, may affect birthing.

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