CHAPTER 5. TRUNK ANATOMICAL MOVEMENTS

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**Introduction**

During pregnancy women report difficulties in everyday tasks (Nicholls and Grieve 1992a) which may be related to changes in trunk mobility and motion control due to increased mass and dimensions. Apposition of body segments and also difficulties in controlling increased angular momentum (Vachalathiti et al 1995) may reduce the functional range of motion of the trunk segments. Increasing the size of the base of support may also be necessary to maintain balance. Although static standing and seated postures have been investigated in previous studies (Bullock-Saxton 1991, Hirao and Kajiyama 1994, Paul and Frings-Dresen 1994), dynamic trunk motion during pregnancy has had very limited investigation. In addition, more complex tasks such as rising from a chair may be affected by limited motion of the trunk segments (Ellis et al 1985). The aim of this study was to investigate the effects of pregnancy on the kinematics of the trunk segments during seated and standing forward flexion, side to side flexion and seated axial rotation. The effect of pregnancy on the size of the base of support adopted for these tasks was also investigated.

**Methods**

Detailed methods for equipment and procedures used for data collection are presented in Chapter 3. Detailed subject descriptions are listed in Appendix 1. In summary, nine maternal subjects and twelve nulliparous control subjects were included in the study. The mediolateral width of the base of support, the displacement of the thoracic and pelvic segments from the start to the end of the motion, and the range of motion of the thoracolumbar spine were investigated during seated and standing stylised anatomical trunk movements.

The subject performed two trials of each movement detailed below at their preferred speed. The starting and finishing position for each movement was an upright posture. For the
forward flexion movements, the subjects’ arms were elevated above the head; for side flexion the arms were by the side, for axial rotation the arms were crossed over their chest. The feet remained flat on the floor throughout the movements and the position was self-selected.

i) Seated and standing forward flexion

The subjects were instructed to reach down towards the floor in front of their feet as far as possible, then bring their straight arms above their head looking upwards. This movement was then repeated. For standing forward flexion the knees were extended.

ii) Seated and standing side to side flexion

The subjects were instructed to bend to the side by sliding the right hand down towards the floor as far as possible letting the head follow the line of the shoulders. They then returned to the upright position, continuing the same movement towards the left side. The cycle of movements was then repeated. Subjects were asked to avoid flexing forward or back and to look forwards throughout the movement.

iii) Seated axial rotation

The subjects turned to the right side while looking over the right shoulder as far as possible. They then returned to the front, visually contacted a fixed marker, and repeated the rotation to the left side as far as possible returning to the centre. The right and left movements were then repeated.

The start and end of forward flexion and side to side flexion movements were defined as a consistent angular velocity in the principal direction greater than 6°/sec for the two point segment defined by thoracic markers T4 and T8. The same criteria were used for seated axial rotation using the two-point segment defined by markers Right ES and Left ES. The
mediolateral width of the base of support was estimated by calculating the mean horizontal distance between the ankles, markers Right lateral ankle and Left lateral ankle.

Initial statistical analysis of side to side flexion and axial rotation was performed on the total motion from the right to the left. In order to investigate the symmetry of the movements, the total motion was then divided into motion to the right and left. The quiet posture before the commencement of movement was used to define the central neutral position. For each session, a repeated measure ANOVA simple contrast was used to test for significant differences between right and left sides.

It was possible that as the trials progressed the subject either fatigued or became more practiced at the movement and therefore the motion was affected systematically as the trials proceeded. Repeated measures ANOVA linear and quadratic contrasts were used to test for the effect of practice or fatigue within each side.

The amplitude of the lumbar spine movement may correlate with the velocity of the trunk movements (Vachalathiti et al 1995). As the subjects self selected their movement speed, it was possible that any changes in amplitude may have been due to differences in velocity. Therefore the correlations between amplitude and time of the movement for trunk forward flexion range of motion seated and standing, seated and standing right and left trunk side to side flexion and seated right and left trunk axial rotation for the thoracolumbar spine, were investigated and analysed using a Pearson product moment correlation coefficient.

Correlation coefficients were interpreted as 0.00 - 0.25 = little if any correlation, 0.26 - 0.49 = low correlation, 0.50 - 0.69 = moderate correlation, 0.70 - 0.89 = high correlation, 0.90 - 1.00 = very high correlation (Domholdt 1993).

Data analysis was performed as described in Chapter 3. In summary, the consistency of performance of control data for each variable over the three test sessions was established.
using intra class correlations, ICC (2,1) (Domholdt 1993). The natural variability for each variable was investigated using the standard error of measurement between control Session 1 and 3. Repeated measures ANOVA (Winer et al 1991) with planned orthogonal contrasts were used to investigate the existence of linear and quadratic trends which would show any systematic change within the control group over the study for each variable. Variables where there was a significant trend and the difference between the means was less than the natural variability were noted in the data tables.

Pregnancy is characterised by continuous changes over time, which may be expected to show systematic changes, as the pregnancy progressed. A repeated measures ANOVA was used to investigate the existence of linear and quadratic trends which would show any systematic change within the maternal group over the four test sessions during pregnancy for each variable. For each variable, where an effect of pregnancy had occurred, the four test sessions were each compared graphically to the control group mean plus and minus twice the standard error and a two tailed student t-test assuming unequal variance was used to confirm any differences seen. The magnitude of the change by the maternal subjects was also compared with the natural variability associated with retesting determined from the control group. If the difference between the means at Session 1 and Session 4 was less than the natural variability a note was made against the significant trend in the data tables listed in Appendix 5. Two tailed Student t-tests assuming unequal variance (Domholdt 1993) were used to compare the maternal postbirth (Session 5) variable results with the control Session 3.

**Results**
Trunk forward flexion

The control subjects' descriptive data and the natural variability associated with retesting for trunk forward flexion are listed in Appendix 5, Table A5i. There were no significant trends over the three sessions for the segment displacements and thoracolumbar spine range of motion in seated and standing forward flexion where the difference between the means was greater than the natural variability associated with retesting. The consistency of performance over the three sessions was fair for the thorax and pelvis segments and good for the thoracolumbar spine in both seated and standing postures. In both postures, the natural variability was a small proportion of the mean for the thorax segment and thoracolumbar spine. For the pelvic segment, however, the natural variability was larger.

The maternal subjects' descriptive data for seated and standing forward flexion motion are listed in Appendix 5, Table A5ii. During seated forward flexion of the trunk there were significant decreasing trends as pregnancy progressed in the thoracic (F_{linear} = 21.16, p = 0.002) and pelvic (F_{linear} = 11.02, p = 0.01) segment displacement and thoracolumbar (F_{linear} = 9.08, p = 0.02) spine range of motion. The maternal group thoracic segment displacement was significantly less than the control group at Session 3 and Session 4 (Figure 5.1). The maternal group pelvic segment displacement was significantly less than the control group at Session 4 (Figure 5.2). The maternal group thoracolumbar spine range of motion, however, was not significantly different from the control group mean at any session (Figure 5.3).
Figure 5.1. Thoracic segment seated forward flexion displacement (mean ± 2 SE) for Maternal Session 1 to 4 and Postbirth (Session 5) and the Control group mean ± 2 SE.

Figure 5.2. Pelvic segment seated forward flexion displacement (mean ± 2 SE) for Maternal Session 1 to 4 and Postbirth (Session 5) and the Control group mean ± 2 SE.
The mediolateral width of the base of support during seated forward flexion showed a significant trend ($F_{linear} = 7.60, p = 0.02$) for increase. The width was significantly greater than the control group mean at Session 3 and 4 as seen in Figure 5.4.

* $p= .008$
* $p= .004$
During standing forward flexion of the trunk there was a significant decreasing trend as pregnancy progressed for the thoracic segment displacement ($F_{\text{linear}} = 13.36, p = 0.006$) and thoracolumbar spine range of motion ($F_{\text{linear}} = 9.97, p = 0.01$). The maternal group thoracic segment displacement and thoracolumbar spine range of motion were significantly less than the control group at Session 4 as shown in Figures 5.5 and 5.6 respectively.

**Figure 5.5. Thoracic segment standing forward flexion displacement (mean ± 2 SE) for Maternal Session 1 to 4 and Postbirth (Session 5) and the Control group mean ± 2 SE.**

**Figure 5.6. Thoracolumbar spine standing forward flexion range of motion (mean ± 2 SE) for Maternal Session 1 to 4 and Postbirth (Session 5) and the Control group mean ± 2 SE.**
The width of the base of support during standing forward trunk flexion showed a significant increasing trend ($F_{\text{linear}} = 7.36$, $p = 0.03$) as pregnancy progressed. The maternal group mean base of support was significantly larger than the control group mean at Session 4 as shown in Figure 5.7.

![Figure 5.7](image-url)

*Figure 5.7. Base of support mediolateral width during standing flexion (mean ± 2 SE) for Maternal Session 1 to 4 and Postbirth (Session 5) and the Control group mean ± 2 SE.*

The correlation between thoracolumbar spine forward flexion range of motion and movement time for both seated and standing postures of the control subjects was negative, indicating as one variable increased the other decreased. The level of correlation was generally low to moderate ($-0.377 \leq r \geq -0.572$), although a high correlation ($r = -0.786$) was seen in seated forward flexion, Session 2. Overall for the control subjects, a weak negative correlation was recorded between thoracolumbar spine range of motion and movement time for seated and standing forward flexion. Maternal subjects showed little to low correlation ($-0.020 \leq r \geq -0.481$) and this did not change as pregnancy progressed.
Postbirth, the thoracic and pelvic segment displacement and thoracolumbar spine range of motion for seated and standing forward flexion showed no significant difference between the maternal group and control group Session 3 (Appendix 5, Table A5iii). There was also no significant difference in the base of support width of the in either seated ($p = 0.51$) or standing ($p = 0.90$) forward flexion.

**Trunk side to side flexion**

The control subjects’ descriptive data and the natural variability associated with retesting for trunk side to side flexion range of motion are listed in Appendix 5, Table A5iv. There were no significant trends over the three sessions in the displacement of the thoracic and pelvic segments and range of motion of the thoracolumbar spine during seated and standing side to side flexion of the trunk in the control subjects. The natural variability was small in comparison to the mean for the thoracic segment and thoracolumbar spine motion, although for the pelvic segment it was comparatively large in both sitting and standing. The consistency of performance was generally good to excellent although the consistency of the thoracic segment displacement in seated posture and the pelvic segment displacement in standing posture were fair and poor respectively.

As pregnancy progressed there were no significant trends for thoracic or pelvic segment displacement or for the thoracolumbar spine range of motion during seated and standing side to side flexion (Appendix 5, Table A5v). The width of the base of support showed a significant trend for increase as pregnancy progressed during seated ($F_{\text{linear}} = 5.51$, $p = 0.046$) and standing ($F_{\text{linear}} = 25.10$, $p = 0.001$) side to side flexion. The base of support widths for side to side flexion were significantly greater than the control group mean at Session 3 and 4 for seated (Figure 5.8) and Session 4 for standing (Figure 5.9).
Figure 5.8. Base of support width during seated side to side flexion (mean ± 2 SE) for Maternal Session 1 to 4 and Postbirth (Session 5) and the Control group mean ± 2 SE.

Figure 5.9. Base of support width during standing side to side flexion (mean ± 2 SE) for Maternal Session 1 to 4 and Postbirth (Session 5) and the Control group mean ± 2 SE.
The postbirth maternal subjects' and control group session 3 descriptive data for seated and standing side to side flexion motion are listed in Appendix 5, Table A5vi. There was no significant difference between the groups for thoracic and pelvic segment displacement and thoracolumbar spine range of motion during side to side flexion. There was also no significant difference between the groups for base of support width during either seated ($p = 0.41$) or standing ($p = 0.86$) side to side flexion.

The left and right motion of the thoracic segment and thoracolumbar spine for the control subjects' seated and standing side flexion are detailed in Appendix 5, Table 5vii. Pelvic segment individual right and left side motion were not investigated as the range of movement of the pelvic segment was found to be relatively small and it was considered unreasonable to further divide the motion into right and left components.

There were generally no significant differences between seated flexion motion to the right and left sides for the thoracic segment and thoracolumbar spine, therefore the side flexion movement in the seated posture was concluded to be symmetrical for the control group. Standing side flexion in the control group, however, was asymmetric with motion to the left being slightly larger although not significantly so for Session 1. For both seated and standing side flexion range of motion, the intersubject variation as indicated by the standard deviation, was relatively high.

It was possible that as the trials progressed within each session that there was a systematic effect of fatigue or practice on the right or left side displacement. Linear and quadratic contrasts, however, showed no significant systematic effects within each session for either seated or standing side flexion motions in the control group (Appendix 5, Table A5vii).

The left and right motion of the thoracic segment and thoracolumbar spine for the maternal subjects' seated and standing side flexion are detailed in Appendix 5, Table 5viii. When left
and right side motion was compared there were generally no significant differences between the sides for either seated or standing side flexion. Therefore there was no significant effect of pregnancy on the right to left side symmetry of trunk side flexion. For the maternal subjects’ Session 1 to Session 3 there was no apparent effect of fatigue or practice as the trials progressed within the session. At Session 4, however, there were significant linear orthogonal contrasts for increase of thoracic segment and thoracolumbar spine side motion in both the seated and standing postures (Appendix 5, Table A5viii).

The correlation between thoracolumbar spine range of motion and movement time for side flexion in the control subjects ranged from little to moderate for both seated (0.021 \leq r \geq 0.513), and standing (0.013 \leq r \geq -0.684) postures and there were no consistent positive or negative correlations. For the maternal subjects, little to low level correlation (0.031 \leq r \geq 0.475) with varying positive and negative sign was seen for both seated and standing side flexion. The relationship between right and left range of motion and movement time did not change as pregnancy progressed.

**Trunk axial rotation**

The control subjects’ descriptive data and the natural variability associated with retesting for seated axial rotation of the trunk are listed in Appendix 5, Table A5ix. There were no significant trends over three sessions in the displacement of the thoracic and pelvic segments and the thoracolumbar spine range of motion in the control subjects. The natural variability associated with retesting was small in comparison to the range of motion for both the thoracic segment and the thoracolumbar spine, however, it was larger for the pelvic segment. The consistency of performance was good for the thoracic segment and thoracolumbar spine, although for the pelvic segment, it was poor.
The maternal subjects' descriptive data for trunk axial rotation range of motion are listed in Appendix 5, Table A5x. As pregnancy progressed there was a significant decreasing trend for the thoracic segment displacement ($F_{\text{linear}} = 9.03, p = 0.02$), pelvic segment displacement ($F_{\text{quadratic}} = 11.4, p = 0.009$) and thoracolumbar spine range of motion ($F_{\text{linear}} = 5.73, p = 0.04$). The pelvic segment displacement, however, was not significantly different to the control group mean at any session as shown in Figure 5.10.

![Graph showing maternal session displacement](image)

*Figure 5.10. Pelvic segment seated axial rotation displacement (mean ± 2 SE) for Maternal Session 1 to 4 and Postbirth (Session 5) and the Control group mean ± 2 SE.*
The thoracic segment displacement and the thoracolumbar spine range of motion were significantly different to the control group mean at Session 3 and Session 4 as shown in Figures 5.11 and 5.12 respectively. The base of support width was not significantly affected as pregnancy progressed ($F_{\text{linear}} = 3.18, p = 0.11$).

**Figure 5.11.** Thoracic segment seated axial rotation displacement (mean ± 2 SE) for Maternal Session 1 to 4 and Postbirth (Session 5) and the Control group mean ± 2 SE.

**Figure 5.12.** Thoracolumbar spine seated axial rotation range of motion (mean ± 2 SE) for Maternal Session 1 to 4 and Postbirth (Session 5) and the Control group mean ± 2 SE.
Postbirth (Session 5) maternal subjects' and control group Session 3 descriptive data for seated axial rotation are listed in Appendix 5, Table 5xi. There were no significant differences between the groups for thoracic or pelvic segment displacement or thoracolumbar spine range of motion. There was also no significant difference ($p = 0.33$) for the width of the base of support between the groups.

The symmetry of the control subjects' seated axial rotation is detailed in Appendix 5, Table 5xii. Pelvic segment displacement was symmetrical to the right and left. The thoracic segment, and hence the thoracolumbar spine however, were asymmetrical with a consistently larger movement to the left. The intrasubject variation as indicated by the standard deviation was relatively high. Linear and quadratic contrasts showed no effect of practice or fatigue as the trials progressed within each session.

The symmetry of the maternal subjects' seated axial rotation is detailed in Appendix 5, Table A5xiii. Thoracic segment axial rotation was asymmetric with motion to the right being consistently larger although not significantly so for Session 3. For the pelvic segment and thoracolumbar spine the motion was symmetrical. The intrasubject variation, as indicated by the standard deviation, for all segments was relatively high. As the trials progressed within each of Session 1 to Session 3 there was no effect of practice or fatigue. Within Session 4, however, there was a significant linear orthogonal contrast ($F_{\text{linear}} = 9.36$, $p = 0.02$) for increase in the thoracolumbar spine side motion.

No correlation ($0.022 \leq r \leq 0.258$) was seen between thoracolumbar spine seated axial rotation range of motion and movement time for both right and left motions for the control subjects. Maternal subjects also showed no correlation ($0.001 \leq r \geq 0.263$) which did not change as pregnancy progressed.
Discussion

The primary objective of this study was to investigate the effect of pregnancy on the kinematics of the thoracic and pelvic segments and thoracolumbar spine during three stylised anatomical trunk motions, forward flexion, side flexion and axial rotation.

Effect of pregnancy on trunk anatomical movements

As pregnancy progresses, apposition of body segments and also difficulties in controlling increased angular momentum may reduce the functional range of motion of the trunk segments. The effect of pregnancy may also not be uniform throughout the trunk as increased mass and dimensions vary across the trunk segments, which may in turn affect the motion of each individual segment.

Trunk forward flexion

In early pregnancy the thoracic and pelvic segment displacements and the thoracolumbar spine range of motion during seated and standing forward flexion were similar to those demonstrated by the control subjects. The control group pelvic segment displacement and thoracic spine range of motion were also similar to previous published reports (Dumas et al 1998b, Gill and Callaghan 1996, Vachalathiti 1994). Some differences to previous published reports were likely to have been due to different methodologies between studies such as the thoracolumbar spine definitions and the starting posture.

As pregnancy progressed the forward flexion motion of the trunk was restricted, although not all trunk segments and postures were similarly affected. For the seated posture, both the thoracic and pelvic segment displacements were significantly decreased in comparison to the control group. The thoracic segment displacement, however, was reduced earlier in the pregnancy than the pelvic segment. For the standing posture, only the thoracic segment
displacement was reduced in comparison to the control group. Similarly, no significant
decrease in pelvic segment displacement during pregnancy for standing forward flexion
was reported by Dumas et al (1998b). It may have been expected that as pregnancy
progressed and the trunk dimensions increased that the forward movement of the trunk
would be obstructed by apposition of the anterior lower trunk on the thighs. As pregnancy
progressed, however, the width of foot placement increased significantly indicating that the
distance between the thighs increased as pregnancy progressed. A wider lower limb
position may have minimised the obstruction of the pelvis motion during forward flexion
until the end stages of pregnancy. Forward flexion of the upper trunk, however, is partly
achieved by reducing the distance between the thoracic cage and the pelvis. As pregnancy
progresses the gravid uterus provides an increasing physical obstruction to the motion of
the thoracic segment, which may have reduced thoracic segment motion.

The thoracolumbar spine range of motion during seated and standing forward flexion was
affected by pregnancy, however, a significant decrease relative to the control group was
seen only for standing forward flexion at 38 weeks gestation. Dumas et al (1998b) also
reported a decrease in lumbar spine range of motion for standing forward flexion as
pregnancy progressed but the range of motion was not significantly different to pre-
pregnancy values. As the thoracolumbar motion was defined as the relative motion
between the pelvic and thoracic segments, the reduction in thoracolumbar spine range of
motion may have been related to the physical obstruction of the thoracic segment
movement by the gravid uterus.

The effect of pregnancy on trunk forward flexion was greater and seen earlier in the
pregnancy for the seated posture verses the standing posture. It may be expected that
greater restriction of seated movement would occur in comparison to standing as the
pregnant abdomen is in very close approximation to the thighs in the seated position and compensation by the hip joints was restricted by the chair. Standing forward flexion, however, may have been more difficult to perform in late pregnancy as forward stability may be decreased. The threat of falling forward may have made the subjects more cautious and less willing to move to physical end of range. Feeling unstable during functional tasks has previously been reported by maternal subjects (Nicholls and Grieve 1992a).

Although the maximum forward flexion motion was restricted as pregnancy progressed, there may be limited effect on some functional tasks requiring forward flexion. Hsieh and Pringle (1994) reported that rising to stand from a chair required only 66% of standing lumbar flexion range of motion while other tasks such as picking up objects from the floor required 95%. Therefore the reduction in late pregnancy to 85% of the standing forward trunk flexion available in early pregnancy may not greatly affect the overall task of rising from a chair if strategies are used to minimise body segment apposition. Adequate space, therefore, must be available in any workspace and an adequate chair size used in order to allow increased width between the feet and also between the thighs for facilitating rising from a chair.

The effect of decreased forward flexion due to physical obstruction, as seen in pregnancy, on the inter relationship between trunk segment motions during functional tasks is unknown. People with low back pain have been shown to compensate for limited lumbar motion by increasing the contribution of the thoracic spine during forward flexion (Lariviere et al 2000). The effect of pregnancy on maximum forward flexion differed between segment and posture. Therefore although the overall reduction in flexion may not greatly affect the task of rising to stand, differing effects on individual segments may lead
to altered movement patterns for functional tasks as pregnancy progresses. Altered movement patterns may also affect the musculoskeletal demands for the segment.

In the control subjects no strong correlation was found between movement time and thoracolumbar spine range of motion similar to previous reports (Marras and Wongsam 1986, Vachalathiti et al 1995). As pregnancy progresses and stability decreases, an increased movement time relative to the forward flexion range of motion may have been a possible strategy to improve stability. For the maternal subjects, however, no correlation was noted in early pregnancy and this relationship was unchanged as pregnancy progressed. The decreased range of forward motion may in itself have increased stability in combination with a wider base of support. Therefore no additional strategy such as reduced velocity was needed.

Postbirth, the thoracic and pelvis segment displacements and the thoracolumbar spine range of motion during seated and standing forward flexion were similar to control group trunk segment motions. The width of the foot placement also was similar to the control group. Dumas et al (1998b) also reported a return to pre-pregnancy values for pelvis segment displacement during standing forward flexion at six and 16 weeks postbirth. Dumas et al (1998b), however, found that although six weeks post birth values for lumbar spine range of motion were similar to pre-pregnant values, the range of motion at 16 weeks postbirth was significantly increased. Unfortunately Dumas and colleagues did not report the effect of repeated testing over a similar time frame. As the variability associated with retesting for this movement in the present study was ± 6.1°, it was possible that the postbirth increase reported by Dumas and colleagues was within this natural variability.

Trunk side to side flexion

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In early pregnancy and postbirth, the thoracic and pelvic segment displacements and the thoracolumbar spine range of motion during seated and standing side to side flexion were similar to those demonstrated by the control subjects. The control group thoracolumbar spine range of motion was also similar to previous published reports (Gill and Callaghan 1996, Lariviere et al 2000, Vachalathiti 1994).

As pregnancy progressed there was no significant effect on the range of motion of the trunk segments, however, the width of the base of support significantly increased. Dumas et al (1998b) also reported no significant differences as pregnancy progressed in lumbar spine range of motion for standing side flexion. It may be expected that the increased trunk circumferences might have little effect on the side to side trunk motion as the increases were more in the anterior rather than lateral direction. The increased mass, however, was likely to have caused decreased stability when moving in the lateral direction. Increasing the width of the base of support may have compensated for the decreased stability.

Postbirth, where mass was reduced in comparison to late pregnancy, the width of the base of support was similar to the control group. Adequate space, therefore, must be available in any workspace in order to allow increased width between the feet when lateral flexion motions are required.

The thoracic and pelvic segment displacement and thoracolumbar spine range of motion was generally symmetrical for seated and standing side flexion to the right and left in both the control and maternal groups. Right to left symmetry of motion for lumbar spine and the thoracic segment for both healthy and low back pain subjects have also been reported (Hindle et al 1990, Lariviere et al 2000). Symmetry of side flexion motion may be expected to continue during pregnancy as the changes in mass and dimensions are also generally symmetrical.
There was also generally no effect of fatigue or practice on the magnitude of the right and left displacements as the trials progressed within each test session for the control subjects and in early pregnancy. At 38 weeks gestation, however, the range of motion of the thoracic segment displacement and the thoracolumbar spine for both seated and standing side flexion increased as the trials progressed. It was possible that as the trials progressed for side flexion the maternal subjects become more convinced of their ability to maintain balance and were thence confident to increase the range of motion.

The correlation between movement time and thoracolumbar spine range of motion was poor and inconsistent for both the control and maternal subjects in contrast to Vachalathiti et al (1995). The movement time, however was not manipulated, therefore a strong correlation could not be expected. In addition as the subjects were asked to perform side flexion at their preferred speed and thus would be expected to remain stable, the need for reduced range seen at higher velocities would not be apparent.

**Trunk axial rotation**

In early pregnancy and postbirth the thoracic and pelvic segment displacement and thoracolumbar spine range of motion during seated axial rotation was similar to the control subjects. The control group mean thoracolumbar spine range of motion was also similar to that reported by Vachalathiti (1994).

As pregnancy progressed the axial rotation motion of the trunk was restricted, although not all trunk segments were similarly affected. The thoracic segment displacement and the thoracolumbar spine range of motion decreased, and was significantly less than the control group by 32 weeks gestation. The pelvic segment displacement, however, was generally similar to the control group throughout pregnancy. During seated axial rotation, the ischial tuberosities and hence the pelvis would be restricted from rotating by contact with the seat.
and pregnancy would not be expected to alter the contact. Therefore no change in pelvic segment displacement as pregnancy progressed would be expected. For the thoracic segment and thoracolumbar spine, it may have possible that as pregnancy progressed and the trunk dimensions increased, that the apposition of the lateral lower abdomen and the ipsilateral thigh increased as pregnancy progressed. The restriction of movement was not thought to be related to stability, as the width of foot placement did not change.

Axial rotation symmetry of motion also differed between the segments. The pelvic segment displacement for both groups was symmetrical to the right and left. As the movement of the pelvis is restricted by contact with the seat, the ability to move more to one side than the other was also restricted, therefore symmetry may be expected. The thoracic segment displacement for both control and maternal groups was asymmetrical, however the asymmetry was in opposite directions. For the control group, axial rotation to the left was 20% larger; while for the maternal group motion to the right was 18% larger. For the thoracolumbar spine range of motion, the control group movements were asymmetrical with the left side 27% larger than the right while the maternal subjects were symmetrical. The pattern of asymmetry / symmetry was generally consistent for all tests for both groups and it was not affected by pregnancy. The pattern may therefore represent the norm for these particular subjects. Hindle et al (1990) noted that there were intersubject differences for symmetry of movement although when results for all subjects were pooled symmetry was seen.

There was generally no effect of fatigue or practice as the trials progressed within each test session for the control subjects and as pregnancy progressed. At 38 weeks gestation, however, the range of motion of the thoracolumbar spine for seated axial rotation increased as the trials progressed. It was possible that in late pregnancy the maternal subjects were
unsure of their ability to move through range as they had experienced difficulties in their
daily activities. For example, Nicholls and Grieve (1992a) reported difficulties in using
seatbelts during pregnancy, performance of which involves axially rotating the trunk to
allow the hand reach across the body to grasp the seatbelt from the door pillar. The
maternal subjects may have been initially not sure of their ability, however, as the trials
progressed the maternal subjects become more confident and increased the range of
motion.

The reduction of seated axial rotation range of motion in the thoracic segment and the
thoracolumbar spine as pregnancy progressed may have implications for the performance
of tasks involving seated trunk rotation. The overall restriction of motion would make such
tasks more difficult to perform. In addition the principal reduction of motion was seen in
the thoracic segment. Therefore as pregnancy progresses, the change in demands on the
musculoskeletal system of the trunk would not be consistent throughout and some areas
may be more affected than others may.

As for side to side flexion, there was no correlation between movement time and
thoracolumbar spine axial rotation range of motion for both the control and maternal
subjects. The movement time, however was not deliberately manipulated, therefore a
strong correlation could not be expected.
Stability of variables associated with retesting

As mass and dimensions of the trunk segments change as pregnancy progresses, a longitudinal multiple retest study design was used. It was possible; however, that changes seen in the variables as pregnancy progressed may have been due to differences related to natural variability with retesting rather than an effect of pregnancy. Therefore nulliparous subjects were used to investigate the consistency of the data over a similar time period to that used for data collection in maternal subjects.

Despite some variability, the consistency related to retesting of thoracic and pelvic segment displacement and thoracolumbar spine range of motion for the three motions over 32 weeks using three test occasions was generally fair to good. The variability possibly reflected both errors in the methodology used, such as small differences in reapplication of markers, and intra subject variation from test to test. The consistency of the thoracolumbar spine range of motion for forward and side to side flexion in standing was generally similar to previous reports for the lumbar spine (Gill and Callaghan 1996, Lariviere et al 2000, McGregor et al 1995, Russell et al 1992, Willems et al 1996). A slightly larger variability was seen from session to session, however, a larger measurement variation would also be expected for the present study as the time period over which repeats were measured was much longer than the one to two days previously reported (Gill and Callaghan 1996, McGregor et al 1995, Russell et al 1992, Willems et al 1996). As range of motion is affected by habitual activity, any retest time period that allows the possibility of changes in habitual activity would necessarily have greater variation.

There were differences in the consistency of the data with retesting for the three motions with axial rotation generally less stable than forward flexion or side to side flexion.
Relatively poor reliability for standing axial rotation of the lumbar spine in comparison to forward flexion and lateral flexion was also reported by McGregor et al (1995).

Differences in consistency of the data with retesting were also seen between the segments tested. For the pelvic segment displacement, the natural variability was relatively large in comparison to the range of motion and the consistency of performance was generally less than the thoracic segment displacement for all three motions. The high variability in pelvic segment displacement from session to session may reflect the many degrees of freedom in the overall task. There may be a range of options in the pelvic segment motion or redundancy may have occurred. It was also possible that although the subjects wore firm fitting underwear or two piece swimming suits during testing, the briefs may have allowed more marker movement and hence error than the firmer fitting bra. As motion of the pelvis during forward flexion, side to side flexion and axial rotation has not been previously reported, the reasons for this difference in retest consistency remained unclear.

**Conclusions**

The trunk segment motions during seated and standing forward flexion and side to side flexion and seated axial rotation were found to be stable with retesting over the time periods used for investigating the effects of pregnancy. The maternal subjects were similar to the control subjects in early pregnancy and at eight weeks postbirth. The maternal subjects used strategies, such as increasing the width of the base of support and reducing obstruction to movements from other body parts, in late pregnancy to attempt to minimise the effects of increased trunk mass and girths. For seated and standing side to side flexion the strategies were successful and no significant decreases in range of motion were seen. For seated and standing forward flexion and seated axial rotation, the motion of both the thoracic segment and the thoracolumbar spine were significantly reduced. Movement of the
pelvis was less affected due to the partial success of minimising obstruction from the thighs by placing the feet further apart during seated and standing forward flexion. The reduction of maximum forward flexion motion may have effects on some functional tasks such as picking up objects from the floor, however, rising to stand from a chair is unlikely to be restricted if strategies are used to minimise body segment obstruction. The differing effect on individual trunk segment motion, however, may lead to altered movement patterns during rising.

The purpose of the study was to investigate the effects of pregnancy on the motion of the trunk segments. The results, however, may also be relevant to considerations of ergonomic issues. The reduction in forward trunk flexion may not greatly affect the overall task of rising from a chair if strategies are used to minimise body segment apposition as were seen in this study. Therefore adequate space may need to be available in the workspace and an adequate chair size used in order to allow increased width between the feet and between the thighs for facilitating rising from a chair. For side flexion tasks adequate space must be available to allow increased width between the feet to ensure side to side stability. The effect of pregnancy was also not consistent across the trunk segments or postures. Therefore the change in demands on the musculoskeletal system of the trunk would not be consistent throughout and some areas may be more affected than others may.