CHAPTER 8. CONCLUSIONS AND RECOMMENDATIONS

The objectives of the study were to investigate seated and standing upper body posture, the kinematics of seated and standing trunk motion, and the three dimensional kinematics and kinetics during rising to stand from a chair as pregnancy progressed and in the early post-birth period. The longitudinal study used an eight-camera three dimensional motion analysis system with two forceplates to investigate a maternal population of convenience, consisting of a mixture of primigravida and multiparous subjects each with a single foetus. The effect of the first pregnancy and a subsequent pregnancy on selected biomechanical variables was also investigated for a single subject.

Pregnancy was characterised by increases in mass and circumference of body segments. Additional mechanical work would be required to move the increased mass and overcome the restriction of motion resulting from apposition of body segments. It was expected that, as pregnancy progressed, movement would become more difficult, stability would decrease and additional propulsion would be required. The effect of increased mass was seen in increased absolute ground reaction forces and lower limb joint moments during rising to stand. Restricted range of motion was also seen in maximum trunk movements.

Contrary to expectations, in the maternal group when rising to stand, forward propulsion was reduced and braking was increased out of proportion to the increase in mass. Postural stability, however, was maintained. Maternal subjects (Nicholls and Grieve 1992a) have reported feelings of instability during daily tasks, therefore a conflict may have existed between the need for additional propulsion and the need for terminal balance at the end of rising. Pai and Lee (1994) suggested that, in non-pregnant subjects, the balance constraint takes precedence over propulsion if these two considerations are in conflict when rising. The use of reduced propulsion and increased braking as pregnancy progressed ensured
terminal balance control. Additional evidence for the priority of stability was also seen in
the increase in maximum seated and standing trunk side flexion as the late pregnancy test
session trials progressed. Maximum side flexion is an inherently unstable motion and not a
common daily activity, so subjects would not be expected to be accustomed to the motion.
In late pregnancy as the trials progressed the subjects gained confidence in their ability to
maintain balance and this was reflected in an increase in the range of motion. Stability was
also increased by the use of a wider foot placement during rising to stand and trunk
motions, and a decreased pre extension phase during free rising to stand.

The increases in segment circumferences as pregnancy progressed were not uniform across
the trunk, with the lower trunk showing the greatest increase. It was therefore considered
possible that the motion of the individual upper body segments may be affected differently
as pregnancy progressed. Different adaptations were seen for the pelvic and thoracic
segments during maximal trunk movements and during rising to stand. Some differences in
postural orientation between segments were also seen for upright sitting and quiet standing,
although the trends were not significant. For some tasks, the differences in motion
appeared to be an attempt to ensure that the task was successful. During upright sitting, for
example, the pelvic segment tended to be more posteriorly orientated as pregnancy
progressed and the thoracolumbar spine more flexed. Therefore the thoracic segment
compensated for the effect of the gravid uterus on the pelvic segment; thus the overall
upright posture was maintained. Another example was seen in free rising to stand, where
the motion of the pelvic segment was unchanged but the increasing demands of the tasks
were met by the increased forward displacement of the thoracic segment.

For other tasks, the differences in motion appeared to be related to the strategies used to
minimise the effects of pregnancy. The pelvic segment peak displacement, for example,
generally remained similar for maximum standing forward flexion and a free rise to stand and only a small decrease was seen for a constrained rise. There was however, an increase in the width of foot placement, which may have been a strategy used to minimise the obstruction of the pelvic segment motion during forward flexion. This strategy was generally successful for both maximum standing forward flexion and for the range of pelvic forward flexion required for rising to stand throughout pregnancy. The strategy was also successful until late pregnancy for a maximum seated forward flexion. Motion 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 as was seen for maximum seated and standing forward trunk flexion and seated axial trunk rotation. A difference between pelvic and thoracic segment motion would therefore be expected.

Although the maternal group as a whole provided insight into biomechanical adaptations as pregnancy progressed, there were also some indications of individual solutions to the mechanical problems of increasing segment dimensions and mass. The response may also differ between pregnancies in an individual. The relatively large variance seen for each postural angle during upright sitting and quiet standing suggested that, as reported by Bullock-Saxton (1991) and Moore et al (1990), women may have individual postural responses, with some increasing and others decreasing their spinal curvatures. Maternal subject 9's postural response in late pregnancy differed between pregnancies, with a neutral thoracolumbar spine postural alignment for the first pregnancy and increased lordosis for the second pregnancy. This subject also showed an individual response for control of forward momentum to maintain terminal stance. For the first pregnancy decreased forward propulsion from the posterior ground reaction forces was combined with reduced thoracic
segment motion and little change in hip joint flexion and for the second pregnancy a reduced range of hip joint motion was combined with increased forward propulsion.

Conclusions

- Altered ground reaction forces and increased lower limb joint moments proportional to increased mass were seen as pregnancy progressed.
- Decreases in forward propulsion force and increases in braking force were proportionally more than increases in mass. Pre-extension phase duration was also decreased. Terminal balance control was thus ensured.
- Stability was increased by the use of a wider base of support.
- The motion of the individual upper body segments differed as pregnancy progressed.
- There were some indications of individual solutions to the mechanical problems of increasing segment dimensions and mass. These responses may also differ between pregnancies in the same individual.

Implication of the results for ergonomic issues during pregnancy and the postbirth period

The purpose of the study was to investigate the effects of pregnancy on rising to stand from a chair. The results, however, may also be relevant to considerations of ergonomic issues.

- The tendency in some subjects for a flatter spinal curve found for upright sitting during pregnancy might have implications for increased risk of injury through reduced ability to absorb vertical vibration forces such as motor vehicles. A flatter spinal curve postbirth during quiet standing may increase the mechanical work to maintain upright posture and result in more rapid trunk muscle fatigue when standing for long periods.
• For standing and seated forward trunk flexion and side flexion tasks adequate space must be provided for increasing width between the feet. During seated and standing forward flexion the increased width between the feet decreases the apposition between the thighs and the anterior abdomen as pregnancy progresses. During seated and standing side flexion, the increased width between the feet increases the postural stability of the movement tasks.

• The increased mass related to pregnancy would result in an increase in the required muscle extension moments and hence increase the mechanical work done in rising to stand. Thus any workplace activity that requires frequent rising from a chair during the work period may need to be limited for women in mid to late pregnancy in order to reduce muscle fatigue. The mediolateral width between the feet increased as pregnancy progressed, which was thought to be a strategy to minimise apposition of the thighs and the anterior abdomen during the forward flexion component of rising to stand. Adequate floor space would therefore need to be available and an adequate chair size used in order to allow increased width between the feet and between the thighs to facilitate rising from a chair.

• The effect of pregnancy was also not consistent across all the trunk segments, postures or movement tasks. Therefore the change in demands, as pregnancy progressed on the musculoskeletal system of the trunk would not be consistent throughout and some areas may be more affected than others.

**Limitations of the Study**

• The statistical power of the study was reduced by the low subject numbers, although a repeated measure design was used to reduce the effect of within-group variability.
The probability of Type I error was increased by the large number of variables and consequent large number of statistical tests. Dividing the alpha level by the number of variables may have reduced the probability of Type I error, however this method would also have reduced the power of each test.

Only a single subject was available for nulliparous, first and second pregnancy testing. A larger sample size would be more representative, however, the practicalities of long term involvement in research of this type inherently limit the availability of such subjects.

The findings related to rising to stand from a chair are limited to height adjustable chairs. Height adjustable chairs, however, are predominantly used in the workplace and therefore the results of the study may be used as a basis for ergonomic research.

**Recommendations for future research**

Further studies with larger subject numbers on smaller areas of interest, as identified by the present study, may benefit from the use of multivariate or multifactoral statistical procedures in order to reduce the number of statistical tests.

The results of this study suggest that horizontal linear momentum was restricted in order to maintain balance at the conclusion of rising to stand from a chair. An investigation of the effect of pregnancy on horizontal linear momentum during rising to stand would be necessary to further support this hypothesis.

The issue of stability during daily tasks has been reinforced by the results of this study. Further study in the areas of stair ascent and descent and lifting, where instability may be magnified, may also be interesting.