Pregnancy produces considerable modifications in the structure and function of the human body to allow for the normal development of the fetus and parturition. Many of these changes, including weight gain,1-3 ligamentous laxity,4,10 and alterations in spinal alignment,11-13 contribute to the characteristic posture and gait associated with the pregnant woman. These alterations, though transient, are believed to lead to the development of postural complaints such as back and lower-extremity pain, which have been found to be common in pregnant women and result in significant morbidity and loss of independence.13-17

Despite the obvious visible changes in gait and posture during pregnancy and the suggested link between these changes and the development of postural symptoms, surprisingly few studies have been conducted specifically to investigate the biomechanics of gait during pregnancy. Research on static postural alterations has revealed changes in the degree of lumbar lordosis11,12 and anterior displacement of the center of mass.18 Anecdotal observations include the development of genu valgum, widening in the base of gait, and increased flatfootedness. Many of these changes are thought to be due to the combined effect of ligamentous laxity and increased body weight.19, 20

To the authors’ knowledge, only three studies have investigated locomotion during pregnancy. Taves et al21 conducted a cinematographic study of two young pregnant women in which the sagittal plane displacements of body segments and spatial parameters (step and stride length) were recorded. The findings suggested that there were no significant differences between pregnant and nonpregnant women, although the authors conceded that modifications in other planes were not considered and, therefore, could not be ruled out. Golomer22 investigated the gait of ten pregnant women while walking and carrying a weight between their third and eighth months of pregnancy. The speed of the subjects did not change throughout the course of the pregnancy, suggesting that the body adapts to the change in posture to minimize energy expenditure.

More recently, Foti et al23 evaluated ten women in the second half of the last trimester of pregnancy, and again at 1 year post partum. Hip, knee, and ankle kinematics and kinetics were recorded using three-dimensional videographic analysis and a force platform. The results of this study suggested that the

---

The Effect of Pregnancy on Footprint Parameters
A Prospective Investigation

ADAM R. BIRD, BPod (Hons)*
HYLTON B. MENZ, BPod (Hons)†
CHRISTOPHER C. HYDE, BA, MEdSt‡

Pregnancy produces significant alterations in the posture of the pregnant woman; however, gait changes that occur during pregnancy have not been adequately evaluated in the literature. This prospective investigation of the footprints of 25 pregnant women from early pregnancy to just prior to parturition revealed a significant increase in the base of gait during walking. This change in gait function may be a compensatory mechanism to improve locomotor stability, and may have important implications for foot function and development of lower-extremity pathology in pregnant women. (J Am Podiatr Med Assoc 89(8): 405-409, 1999)
characteristic features of a “waddling” gait—that is, increased base of support and foot-progression angle—were not more evident during pregnancy, leading the authors to conclude that gait changes during pregnancy are relatively mild.

Given the paucity of literature available that pertains specifically to locomotion during pregnancy, this prospective study was undertaken to evaluate whether pregnancy has an effect on selected spatial and angular parameters of gait by evaluating footprints at various stages during pregnancy. It was hypothesized that pregnancy would produce significant increases in both base and angle of gait as a compensatory mechanism for the increase in body weight and ligamentous laxity.

**Materials and Methods**

**Subjects**

Ethical approval was obtained for the study from the La Trobe University and Royal Women’s Hospital ethics committees. Thirty-four pregnant women were recruited over a 4-month period. The participants consisted of women attending prenatal clinics of the Royal Women’s Hospital and Essendon Hospital in Melbourne, Australia. At the time of the initial assessment, subjects were recruited at approximately 12 weeks’ gestation, plus or minus 4 weeks (mean [±SD], 13.00 ± 2.24 weeks). This range was considered appropriate, as this was the first clinic visit for the majority of the women, and it was assumed that there would not be any significant changes in gait at this early stage of pregnancy. There were no other specific criteria for selection of subjects. Of the original 34 subjects enlisted, 9 were excluded during the course of the study because of miscarriage, change of hospital providing prenatal care, or illness, reducing the sample size to 25. Fifteen women were having their first child, and ten women were undergoing a subsequent pregnancy.

At the initial measurement session, the subjects’ age, weight, and height were recorded. The means (±SD) of these measurements were as follows: age, 28.7 ± 5.3 years; weight, 66.8 ± 15.4 kg; and height, 162.8 ± 5.8 cm.

**Experimental Setup and Protocol**

Footprint data were obtained from each subject using a previously described technique. This method involves the subject’s standing in a box containing a colored powder paint and talc mixture, and then walking along a 5-m-long, 1-m-wide walkway made of cardboard. At least five footprints (deemed representative by the investigators) were obtained and then affixed with a fixative spray for subsequent analysis. The parameters obtained from the footprints are presented in Figure 1. A number of footprint parameters can be measured from each sheet, including angle of gait, base of gait, step length, stride length, and foot length. A transparent grid of parallel lines was placed on each footprint under consideration to obtain a longitudinal bisection of the foot as well as a bisection of each heel print, from which measurements were taken with a 1.5-m ruler (Fig. 1A). The high reliability of measurement of these parameters has been demonstrated in a previous report.

Footprint data were recorded every month from the initial assessment until parturition; thus a total of six sets of measurements were recorded.

**Results**

**Data Analysis**

A multivariate repeated-measures analysis of variance (ANOVA) was chosen as suitable for analysis of the data. Each dependent variable was analyzed separately. After the initial repeated-measures ANOVA yielded significant results, the Tukey’s honestly significant difference statistic was calculated to determine which of the mean values from the data-collection sessions were significantly different from each other. The results are presented in Table 1.

Two dependent variables (body weight and base of gait) increased significantly between sessions 1 and 6 (α = .05), while body weight also increased significantly from one session to the next. The mean base of gait at the first measurement session (13 weeks’ gestation) was 66.4 ± 26.4 mm, and this value increased to 85.6 ± 33.8 mm just prior to parturition, representing a mean increase of approximately 30% (Fig. 2). It should be noted, however, that the standard deviations for base of gait values were large, indicating considerable variability between individual subjects. For example, initial base of gait measurements ranged from 15 to 120 mm, and the change in the base of gait from the first session to the last session ranged from an increase of 70 mm to a decrease of 4 mm. Nevertheless, the statistical analysis reveals a significant trend toward an increase in base of gait from the first to the last measurement session. A regression calculation to further investigate this suggested trend within the base of gait data means of each session was also performed, with a Pearson’s $r$ value of .87 derived, which indicates a high degree of correlation between the variables (Fig. 2).
No significant differences were observed between subjects with regard to whether they were experiencing their first or subsequent pregnancies.

Discussion

The finding of an increase in base of gait is in agreement with the authors’ hypotheses; however, the angle of gait did not significantly change during the course of pregnancy. In addition, no other footprint parameters (stride length, step length, foot length) changed significantly between measurement sessions.

The functional significance of the base of gait—which has also been referred to as stride width,26-28 base of step,29 and base of support30—has not been fully established, but it is thought to influence gait stability. In one of the earliest studies on footprint parameters, Murray et al26 reported a mean base of gait of 80 mm in 60 men, and in a subsequent investigation reported a smaller mean value of 69 mm in 30 women27; however, no explanation for this difference was offered. Rigas28 reported larger base of gait val-

Table 1. Mean (±SD) Results from Repeated-Measures Analysis of Variance for Sessions 1 and 6

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Session 1</th>
<th>Session 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight (kg)</td>
<td>66.8 ± 15.4</td>
<td>78.5 ± 15.4&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Base of gait (mm)</td>
<td>66.4 ± 26.4</td>
<td>85.6 ± 33.8&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Left angle of gait (°)</td>
<td>8.5 ± 3.7</td>
<td>9.8 ± 4.1</td>
</tr>
<tr>
<td>Right angle of gait (°)</td>
<td>9.5 ± 3.6</td>
<td>10.4 ± 3.7</td>
</tr>
<tr>
<td>Step length (cm)</td>
<td>56.0 ± 6.6</td>
<td>58.0 ± 6.4</td>
</tr>
<tr>
<td>Stride length (cm)</td>
<td>110.7 ± 13.3</td>
<td>114.3 ± 13.2</td>
</tr>
<tr>
<td>Left foot length (cm)</td>
<td>23.7 ± 1.2</td>
<td>23.7 ± 1.1</td>
</tr>
<tr>
<td>Right foot length (cm)</td>
<td>23.7 ± 1.3</td>
<td>23.7 ± 1.1</td>
</tr>
</tbody>
</table>

<sup>a</sup>Significant difference at α = .05.

Figure 2. Mean and standard error values for the base of gait during the course of pregnancy (Pearson’s r = .87).
ues in a group of subjects aged 65 to 90 years, and suggested that older people have relatively weak hip abductors and therefore adopt a wider base to improve gait stability. A wider base of gait has also been observed in children with Down syndrome\textsuperscript{31} and when normal children walk more slowly than at their regular cadence.\textsuperscript{32}

The finding of an increased angle of gait in this investigation of pregnant women supports previous clinical observations,\textsuperscript{19, 20} but is contrary to that of Foti et al,\textsuperscript{23} who reported no difference between base of gait values for pregnant and postpartum measurements. However, given that a within-subjects design was used in the study by Foti et al, there is a possibility that the postpartum analysis reflected residual changes that remained following the pregnancy and thus the postpartum measurements may not be considered normal for comparison.

There are two possible explanations for the increase in base of gait observed in this study. First, widening the base of gait would seem to be a useful strategy during pregnancy, when the body’s equilibrium demands are substantially challenged by alterations in the center of mass and ligamentous laxity. Widening the base of gait will increase the functional base of support during walking, producing a larger area in which the center of mass can deviate from step to step. Second, any weight gain to the thigh region will act to increase the abduction of the hips to enable free passage of the swing limb, an observation initially reported in obese men by Spyropoulos et al.\textsuperscript{33}

The functional consequences of an increased base of gait for the lower limb in pregnant women have not been adequately discussed in the literature; however, a number of authors have suggested a causal link between clinically observed structural changes and development of lower-limb pathology. For example, Root et al\textsuperscript{20} suggested that an increased base of gait and genu valgum have the combined effect of directing body weight medial to the talus, producing excessive foot pronation and subsequent pathology. This suggestion is supported by Block et al,\textsuperscript{9} who reported a decrease in arch height in 13 pregnant women and suggested a causal link between altered foot position and lower-extremity symptoms. Although this pathomechanical compensation pattern has little evidence to support it, foot pain is common in pregnancy and therefore the mechanisms underlying foot pathology warrant further investigation.

**Limitations**

Ideally, a preconception baseline with which to compare subsequent measurements would have been useful, but this is clearly impractical. Similarly, postpartum measurements would have been advantageous to determine whether there are any residual changes to gait during pregnancy, or if footprint parameters returned to their values during early pregnancy. Anecdotally, a number of the women in this study suggested that they did indeed have residual changes to their feet and walking styles after giving birth to their children.

Another limitation of this study is that the number of footprints obtained was small and measurements were obtained when the women were well rested. Therefore, this study may not provide a valid representation of gait changes that occur in pregnant women when they have walked a reasonable distance and are experiencing fatigue. It could be reasonably suggested that pregnant women become fatigued relatively quickly because of increased metabolic demands, and the characteristic gait changes observed clinically may be evident only with fatigue.

**Indications for Further Research**

The potential scope of related research topics within the field of gait during pregnancy is significant. The determination of whether fatigue has an effect on gait during pregnancy should be investigated by evaluating footprint parameters before and after exercise. Further kinematic studies are required to elucidate the changes in lower-limb and spinal function during pregnancy, and to clarify the suspected relationship between excessive foot pronation and low-back pain.\textsuperscript{34} In addition, analysis of postpartum gait function is required to determine the possible residual effects of pregnancy on locomotor function.

**Conclusion**

Gait modifications during pregnancy have not been fully evaluated in the literature, despite the suggested causal link between locomotor dysfunction and lower-extremity pathology in pregnant women. This prospective study has revealed that pregnancy is associated with a significant increase in the base of gait. This change in gait function may be a compensatory strategy to improve stability during walking by increasing the functional base of support. Further research is required to determine whether a causal relationship exists between gait modifications during pregnancy and the development of lower-extremity symptoms.

**Acknowledgment.** Supported by a grant from Allied Health Industries Pty Ltd, Sydney, Australia.
References