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The "Accommodation and Occupational Safety for Pregnant Military Personnel" Study (commonly referred to as Pregnant Women's Study or PWS) is a cooperative effort between the United States Air Force 74<sup>th</sup> Medical Group, Armstrong Laboratory's *Computerized Anthropometric Research and Design (CARD)* Laboratory, and *SYTRONICS, Incorporated* under a research grant from the U.S. Army Medical Research and Materiel Command. The purpose of this Study is to collect a set of traditional anthropometric data as well as a three-dimensional whole body scan data set for a sample population of approximately 25 pregnant women. This Study will address body shape changes during pregnancy.

The Study objectives are to:

- Characterize size and shape changes for a sample population of 25 pregnant women, and
- Provide recommendations for future research that evaluates the occupational constraints placed on pregnant women due to their changing body size and capabilities.

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**INTERIM REPORT  
FOR  
ACCOMMODATION AND OCCUPATIONAL SAFETY FOR  
PREGNANT MILITARY PERSONNEL**

1.0            **INTRODUCTION**

The "*Accommodation and Occupational Safety for Pregnant Military Personnel*" Study (commonly referred to as the Pregnant Women's Study or PWS) is a cooperative effort between the United States Air Force 74<sup>th</sup> Medical Group, Armstrong Laboratory's *Computerized Anthropometric Research and Design (CARD)* Laboratory, and *SYTRONICS, Incorporated* under a research grant from the U.S. Army Medical Research and Materiel Command. The purpose of this study is to collect a set of traditional anthropometric data as well as a three-dimensional whole body scan data set for a sample population of approximately 25 pregnant women. This study addresses body shape changes during pregnancy.

The study objectives are to:

- *Characterize size and shape changes for a sample population of 25 pregnant women, and*
- *Provide recommendations for future research that evaluates the occupational constraints placed on pregnant women due to their changing body size and capabilities.*

1.1            **Subject**

The number of women working today has increased more than tenfold since World War II (Chavkin, 1986). It is estimated that about 85% of the female labor force will become pregnant at some point during their career (Chavkin, 1986). Therefore, pregnant women are a significant portion of the workforce, and more than 75% of those pregnant for the first time continue working into their third trimester (Nicholls and Grieve, 1992).

The military no longer considers pregnancy a basis for automatic discharge, so there are increasing numbers of women in the military. Because of revised regulations, women are expected to perform their assigned tasks during pregnancy. At the onset of pregnancy, many active-duty women may be exposed to a number of occupational high-risk factors--lifting heavy objects (up to 45 pounds) or working in confined spaces (i.e., in tanks or underground). Their duties also may entail prolonged bending, stooping, twisting, standing, or sitting.

Until now, little attention has been given to the accommodation and safety of pregnant military women. In fact, there are no guidelines that address physical accommodation requirements for pregnant, active-duty military women. The rising number of military women has created a need

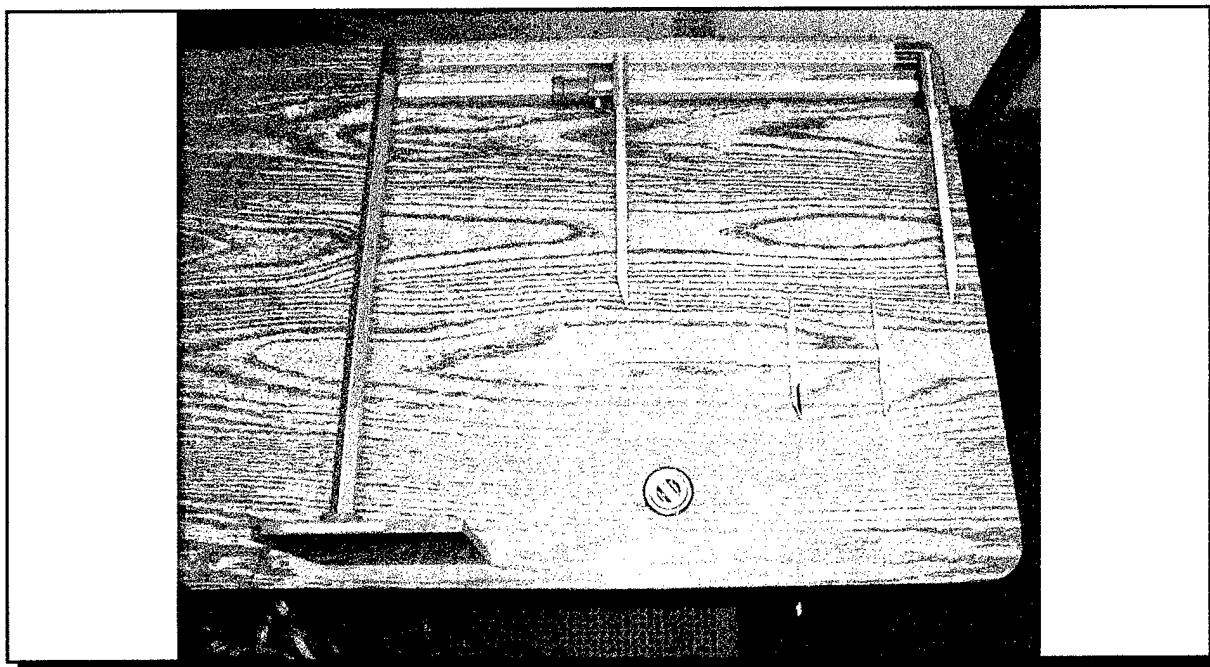
for research on the occupational limits imposed by a pregnant woman's increasing body size and reach constraints. To date, no significant data collections provide *three-dimensional (3-D)* anthropometry measurement of shape changes during pregnancy. A 3-D data set that clearly identifies a woman's shape changes during pregnancy will help designers and policy-makers define and improve the work environment for pregnant women.

## 1.2 Purpose

The purpose of this study is to collect a traditional anthropometric data set and a 3-D whole body scan data set for a sample population of approximately 25 pregnant women. This study addresses the body size and shape changes associated with pregnancy and the impact these changes may have on occupational performance during pregnancy.

## 1.3 Scope

This study addresses the body size and shape changes that occur during pregnancy. Traditional anthropometric data are being collected using standard anthropometric tools such as calipers, tape measurers, and anthropometers (see Figure 1.3-1).



**FIGURE 1.3-1. Traditional Anthropometric Tools--Caliper, Tape Measurer, and Anthropometer**

The 3-D data are being gathered using the Cyberware laser surface whole body scanning system (see Figure 1.3-2). The traditional anthropometric data provide the *size* change

associated with pregnancy while the 3-D anthropometric data provide the *shape* change undergone during pregnancy. Both the traditional and the 3-D anthropometric data are being collected on approximately 25 pregnant women throughout the pregnancy term. The subject pool consists of personnel available through the Wright-Patterson Regional Medical Center--Obstetrics and Gynecology Flight. These data can contribute to on-going military research addressing human modelling for specific workstation accommodation studies in both seated and standing positions.

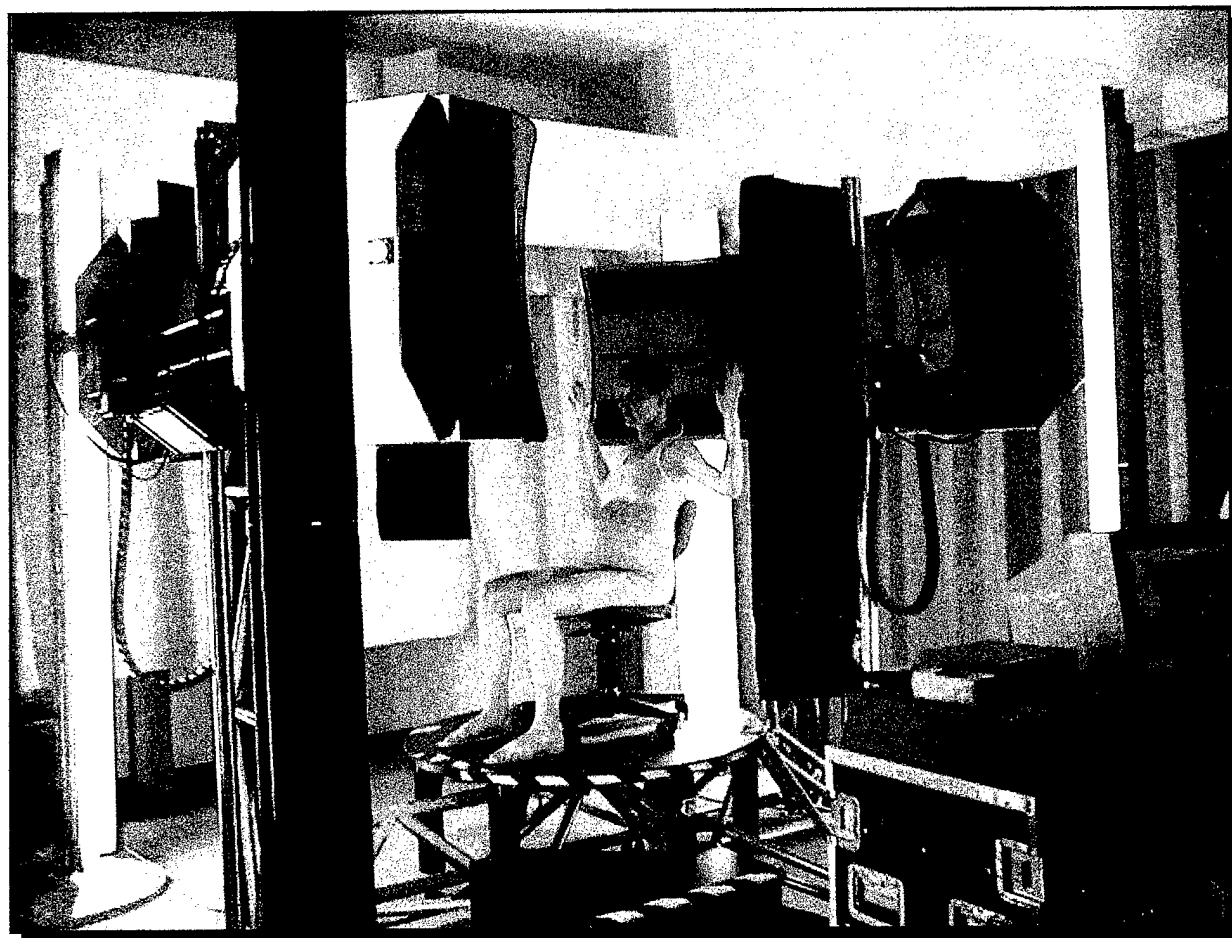


FIGURE 1.3-2. Cyberware Whole Body Laser Scanner

## 2.0 **BODY**

### 2.1 Experimental Methods

#### 2.1.1 Study Procedures

This study is designed to collect traditional anthropometric data, demographic data, occupational information, and three-dimensional anthropometric data.

#### 2.1.2 Subject Recruitment

Due to factors such as pregnant women leaving the military service, relocating to a different geographical area, experiencing medical complications, not carrying the baby full-term, and electing to drop out of the study prior to completion, it was necessary to begin the study with as close to 50 females as possible to obtain an end sample size of 25 females.

The subject recruitment efforts were focused on the Wright-Patterson Regional Medical Center--Obstetrics and Gynecology Flight, Wright-Patterson Air Force Base, Ohio. Ms. Teresa Crase and Ms. Sherri Blackwell attended weekly orientation meetings for pregnant women which were held at Wright-Patterson Regional Medical Center in the Dental Clinic Conference Room. On the average, 15 pregnant women attended each weekly meeting. During these meetings, Ms. Crase and Ms. Blackwell briefly described the study and invited pregnant women to participate. Interested participants signed up for the study and their questions were answered.

Subject recruitment proved more difficult than expected. To reach as many potential subjects as possible, efforts were expanded to include two local doctors' offices to recruit women to participate as subjects.

To help advertise for the study, a brochure was printed (Appendix A). Brochures were distributed to women at the weekly orientation meetings and to pregnant women at local doctors' offices. Brochures were also posted at local baby retail stores. Two articles were published in the *Skywriter* (Appendix B), a weekly newspaper produced and distributed at Wright-Patterson Air Force Base. The full-scale effort to recruit subjects ended May 1997, when 35 subjects had enrolled.

#### 2.1.3 Subject Participation

In order to be accepted into the study, the subject had to meet several qualifications. Only women between the ages of 18 and 40 years of age were allowed to participate, and all subjects had to start the study while they were in their first trimester (before any noticeable weight and/or body changes occur). The target population includes active-duty military women; however, the small number of available subjects required that the sample be augmented. Therefore, civilian women were encouraged to participate as long as they met the military height and weight requirements

before they became pregnant. The military height and weight requirement chart used to determine qualification for participation in this study is included in Table 2.1.3-1.

**TABLE 2.1.3-1.**  
**Military Height/Weight Requirement Chart**

*(Used for the Accommodation and Occupational Safety for Pregnant Military Personnel Study)*

<b>U.S. AIR FORCE AND U.S. NAVY HEIGHT/WEIGHT REQUIREMENTS FOR AVIATORS</b>							
<i>Female</i>							
STATURE (in)	58.0	59.0	60.0	61.0	62.0	63.0	64.0
STATURE (cm)	147.3	149.9	152.4	154.9	157.5	160.0	162.6
MAX WT	126.0	128.0	130.0	132.0	134.0	136.0	139.0
MIN WT	87.0	89.0	92.0	95.0	97.0	100.0	103.0
STATURE (in)	65.0	66.0	67.0	68.0	69.0	70.0	71.0
STATURE (cm)	165.1	167.6	170.2	172.7	175.3	177.8	180.3
MAX WT	144.0	148.0	152.0	156.0	161.0	165.0	169.0
MIN WT	106.0	108.0	111.0	114.0	117.0	119.0	122.0
STATURE (in)	72.0	73.0	74.0	75.0	76.0	77.0	78.0
STATURE (cm)	182.9	185.4	188.0	190.5	193.0	195.6	198.1
MAX WT	174.0	179.0	185.0	190.0	196.0	201.0	206.0
MIN WT	125.0	128.0	130.0	133.0	136.0	139.0	141.0
STATURE (in)	79.0	80.0					
STATURE (cm)	200.7	203.2					
MAX WT	211.0	216.0					
MIN WT	144.0	147.0					

Figure 2.1.3-1 contains the height and weight distribution of subjects at the first session. The initial session height and weight are not necessarily the pre-pregnancy height and weight. Subjects ranged from three weeks pregnant to 16 weeks pregnant at the first session.

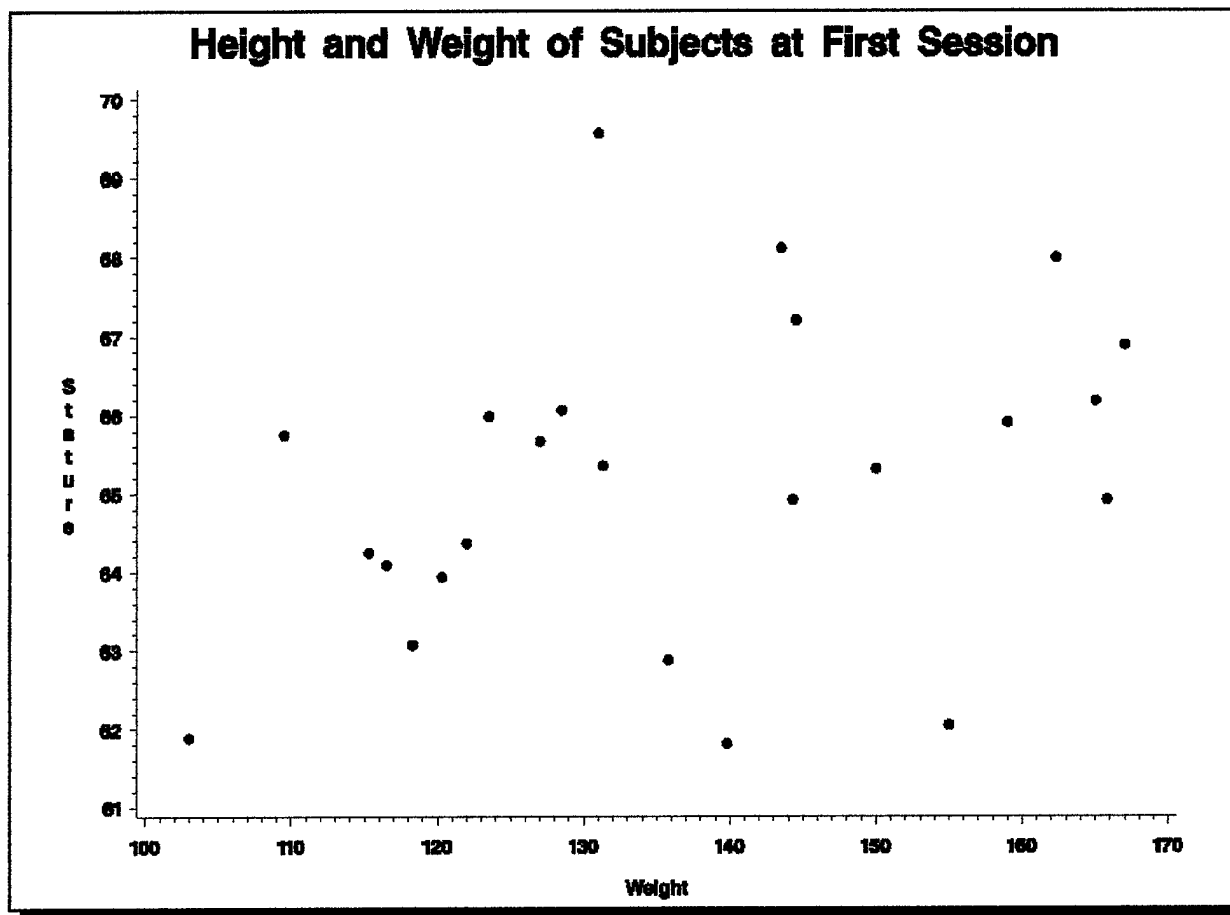


FIGURE 2.1.3-1. Height and Weight Distribution of Subjects at the First Session

The number of hours the subject spent at the data collection site (CARD Lab) and the number of miles she drove to get to the Lab are recorded at the end of each data collection session. A payroll record form which contains this information is kept for each subject (Appendix C). At the end of each month, **SYTRONICS** sends each non-military subject a check for the total time contributed to the study and reimbursement for miles driven to and from the Lab for that month. Active-duty military women are not paid for time or mileage; non-military subjects are paid \$8.00 an hour and \$.30 per mile traveled.

#### 2.1.4 Data Collection

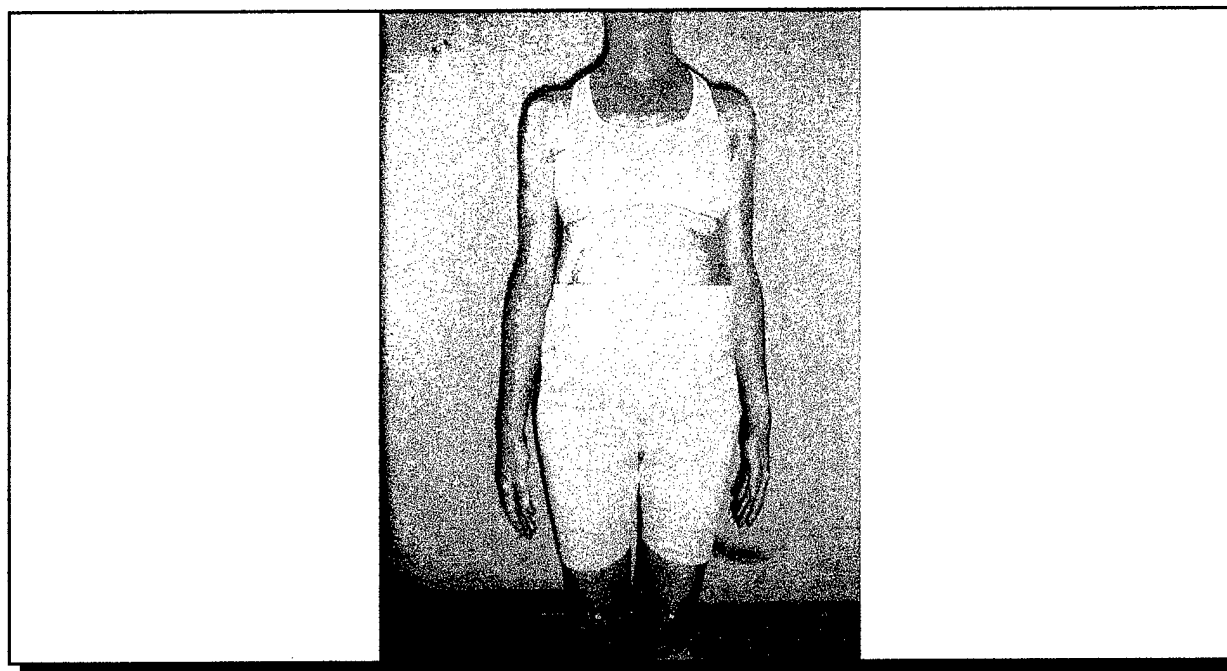
There are six data collection sessions per subject. The sessions are spread out over 40 weeks of pregnancy in order to capture as much size and shape change as possible. One data collection session is conducted during the first trimester, one session during the second trimester, three sessions during the third trimester, and one post-delivery session. Most abdominal change occurs in the third trimester, therefore, half of the data is collected during this period of gestation.

The first session, or baseline session, is completed prior to noticeable weight and body changes and/or by the end of the first trimester. For example, one subject was measured as early as three weeks and another as late as 16 weeks for the first session. The second session is scheduled to be completed at 20 weeks; the third session, between 28-29 weeks; the fourth session, between 32-33 weeks; and the fifth session, between 37-38 weeks. The sixth session, which is the post-delivery session, should be completed within a month after delivery.

Subjects are scheduled for sessions as close to the planned number of weeks as possible. Sometimes it is impossible to complete sessions at the desired time due to scheduling conflicts, illness, holidays, vacations, or lack of transportation. Therefore, the earliest possible time was scheduled.

### 2.1.5 Demographic and Traditional Anthropometric Data

Prior to the collection of traditional anthropometry (measurement of the human body with calipers and tape measurers, Figure 1.3-1, page 2), anatomical landmarks (physical manifestations common to all humans as a species) are located and marked using an eyeliner pencil and adhesive blue dots. Figure 2.1.5-1 shows a subject with landmarks.



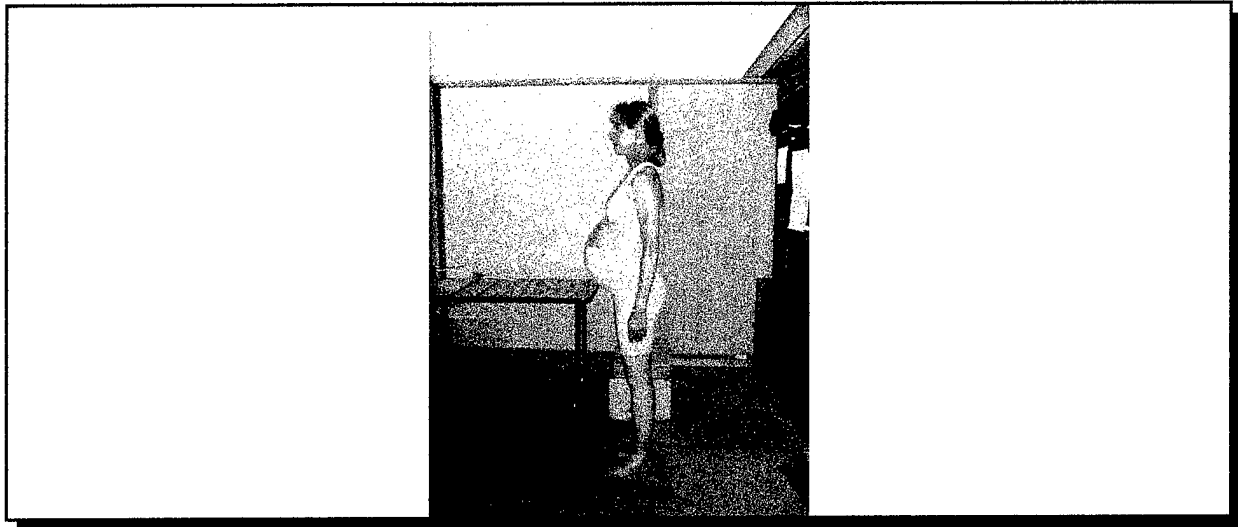
**FIGURE 2.1.5-1. Subject With Anatomical Landmarks**

Landmarks are used as three-dimensional points for aligning the scan data within the same axis system. A data collection sheet including the 37 dimensions measured is included in Table 2.1.5-1. Subjects are required to take a break every 10 minutes during the traditional anthropometric data collection process to keep them from becoming overtired by the strict postures.

**TABLE 2.1.5-1.**  
**Anthropometric Data Form**

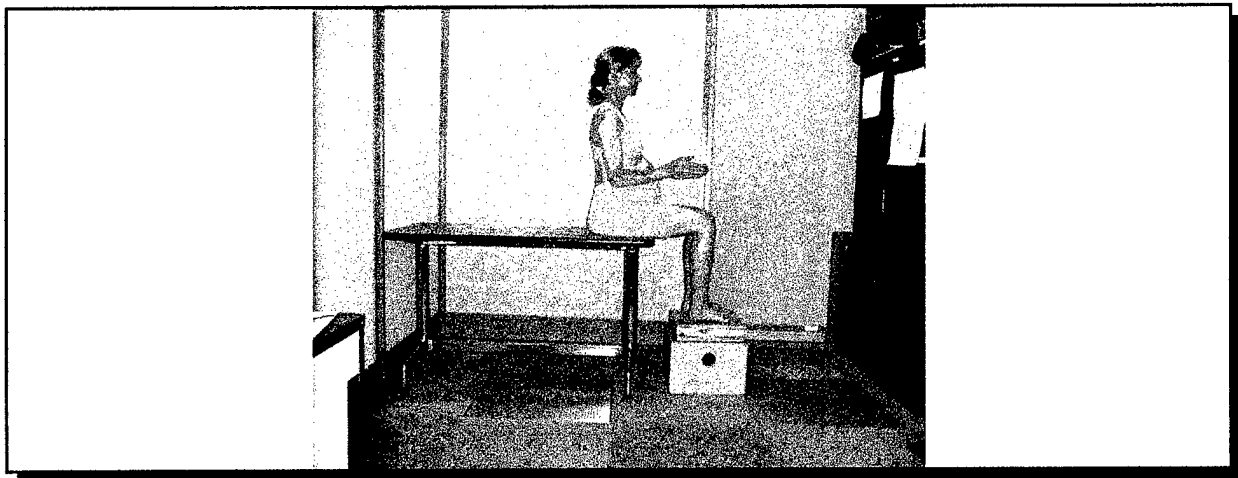
<b>ANTHROPOMETRIC DATA FORM</b>	
<i>(Measurement Values in cm)</i>	
<b>SUBJECT NO.:</b>	<b>DATE:</b>
<b>NAME:</b>	<b>DATE OF BIRTH (MM/DD/YY):</b>
<b>AGE:</b>	<b>LOCAL PHONE NO.:</b>
<b>PREGNANCY:</b> <input type="checkbox"/> 1 <sup>st</sup> <input type="checkbox"/> 2 <sup>nd</sup> <input type="checkbox"/> 3 <sup>rd</sup> <input type="checkbox"/> Other: _____	<b>ADDRESS:</b> _____ _____ _____
<b>RACE:</b>	
<input type="checkbox"/> White <input type="checkbox"/> Hispanic <input type="checkbox"/> Asia or Pacific Islander <input type="checkbox"/> Black <input type="checkbox"/> American Indian or Alaska Native <input type="checkbox"/> Other (Please specify): _____	
<b>DO NOT WRITE BELOW THIS LINE</b>	
Thumbtip Reach, Right _____	Chest Depth _____
Weight _____	Chest Depth Below Bust _____
Stature _____	Waist Depth, Preferred _____
	Waist Depth, Omph. _____
Cervicale Height _____	Chest Circumference _____
Suprasternale Height _____	Chest Circ. Below Bust _____
Substernale Height _____	Waist Circ., Preferred _____
Chest Height _____	Waist Circ., Omph. _____
Chest Height Below Bust _____	Hip Circumference _____
Tenth Rib Height _____	Thigh Circ., Proximal _____
Waist Height, Preferred _____	Calf Circumference _____
Waist Height, Omph. _____	Ankle Circumference _____
Patella Top Height _____	Foot Breadth _____
Chest Breadth _____	Sitting Height _____
Chest Breadth Below Bust _____	Cervicale Height, Sitting _____
Waist Breadth, Preferred _____	Knee Height, Sitting _____
Waist Breadth, Omph. _____	Buttock-Knee Length _____
Hip Breadth _____	Abdominal Ext., Depth, Sit _____
	Hip Breadth, Sitting _____
	Hand Breadth _____
<b>SIGNATURES</b>	
<b>MEASURER:</b>	<b>RECORDER:</b>

For most measurements, the subject stands in an upright, straight posture with heels together and toes apart. The measurer positions the subject's head in the Frankfurt Plane, with the pupils on the same horizontal level, and the right tragion (approximately by the ear hole) and the lowest point of the right orbit (eye socket) on the same horizontal plane. Figure 2.1.5-2 shows a subject with her head positioned in the Frankfurt Plane.



**FIGURE 2.1.5-2. Frankfurt Plane--Proper Head Position for Standing Posture for Anthropometric Data Collection**

For measurements on a seated subject, the measurer arranges the horizontal surfaces of seat and foot so that the thighs are horizontal, the lower legs are vertical, and the feet flat on their horizontal support (Kroemer, 1989). Figure 2.1.5-3 shows a subject in the seated posture for traditional anthropometric data collection. Foot boxes are used to align the knee to a 90° angle as shown.



**FIGURE 2.1.5-3. Sitting Posture for Anthropometric Data Collection**

Appendix D contains a list of landmarks, list of dimensions, landmark descriptions, dimension descriptions, and a glossary of related terms.

#### 2.1.6 Occupational Information

Each subject will complete a general questionnaire before completing the study. The questionnaire covers a broad range of topics related to the subject's work environment. Questionnaire responses will be collated once all of the subjects have completed the questionnaires. Appendix E contains the completion questionnaire.

#### 2.1.7 Three-Dimensional Anthropometric Data

The Cyberware WB4 Whole Body Scanner is used to scan the subjects during each session. Figure 2.1.7-1 shows a subject being scanned by the Cyberware WB4 Whole Body Scanner. The Cyberware WB4 Whole Body Scanner is a 3-D digitizer used to capture surface shape and color information on the human body as a single entity. The lasers in the scanner heads create a low-power, vertical plane-of-light which shines on the surface of the subject. The light reflects the contour images of the subject through a series of mirrors and prisms to cameras which digitize the image. The scanner can cover a volume of 2 meters high and 1.2 meters in diameter. One scan takes less than 20 seconds which helps to minimize errors due to movement and swaying. A scan evaluation form is completed for each subject during every session. The scan evaluation form contains information regarding the subject, the size of experimental clothing worn, the filename of the scans, scanner data, and general comments. Table 2.1.7-1 includes the scan evaluation form. Subjects are scanned in both a seated and a standing posture.



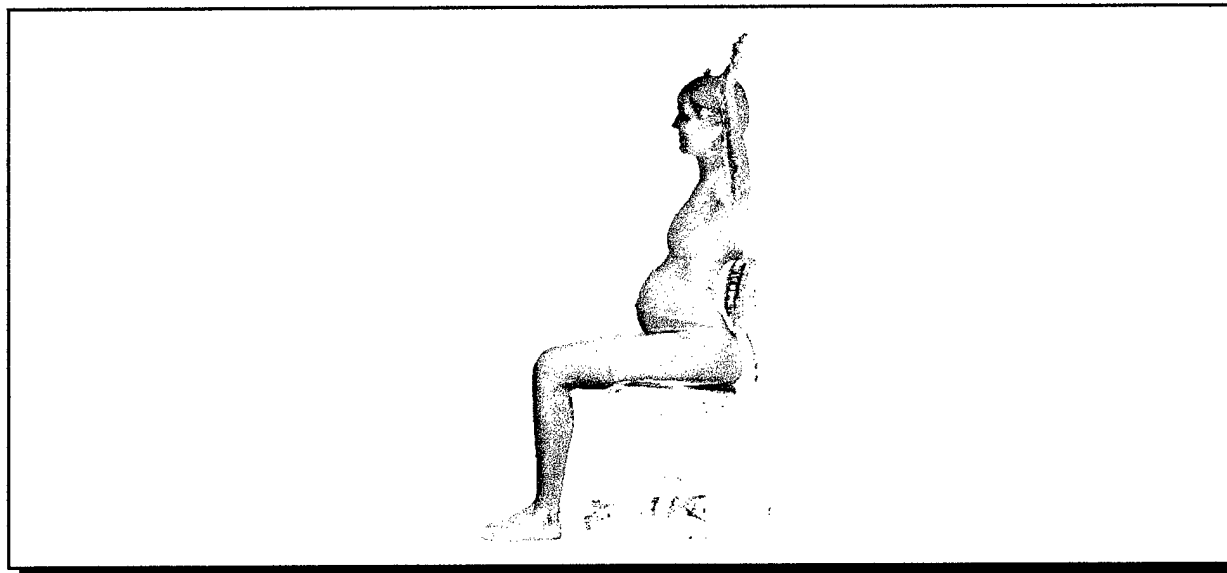
**FIGURE 2.1.7-1. Subject Being Scanned by the Whole Body Scanner**

**TABLE 2.1.7-1.  
 Whole Body Scan Evaluation Form**

<b>WHOLE BODY SCAN EVALUATION FORM</b>				
<b>① SUBJECT DATA</b>				
SUBJECT NAME:			SUBJECT NO.:	
DATE OF BIRTH:	RACE:		PLEASE CHECK (✓) ONE:	
____/____/____ Day      Month      Year	<input type="checkbox"/> White <input type="checkbox"/> Black <input type="checkbox"/> Hispanic <input type="checkbox"/> Asian <input type="checkbox"/> American Indian/Alaska Native <input type="checkbox"/> Other: _____		<input type="checkbox"/> Military <input type="checkbox"/> Civilian	
<b>② EXPERIMENTAL DATA</b>				
FILENAME:	DATE:	SCAN NO.:		
<b>③ BODY DATA</b>				
SKIN ARTIFACTS (e.g., wrinkles, scars, etc.):		HEAD HAIR COLOR:		
HEAD HAIR LENGTH:		HEAD HAIR STYLE:		
<input type="checkbox"/> Short <input type="checkbox"/> Medium <input type="checkbox"/> Long				
POSTURE COMMENTS:				
<b>④ CLOTHING INFORMATION</b>				
CAP SIZE:	SHORT SIZE:	BRA SIZE:		
REMARKS ON CLOTHING FIT:				
<b>⑤ SCANNER DATA</b>				
	HEAD 1	HEAD 2	HEAD 3	HEAD 4
Sensitivity	60	60	70	70
<b>⑥ SCANNING EVALUATION</b>				
	SCAN 1 - STAND		SCAN 2 - SIT	
Head Rotation				
Movement Artifacts				
Missing Data				
Reflections				
GENERAL COMMENTS:				

### 2.1.8 Sitting

The seated scanning posture maximizes body surface coverage and landmark visibility (Figure 2.1.8-1).



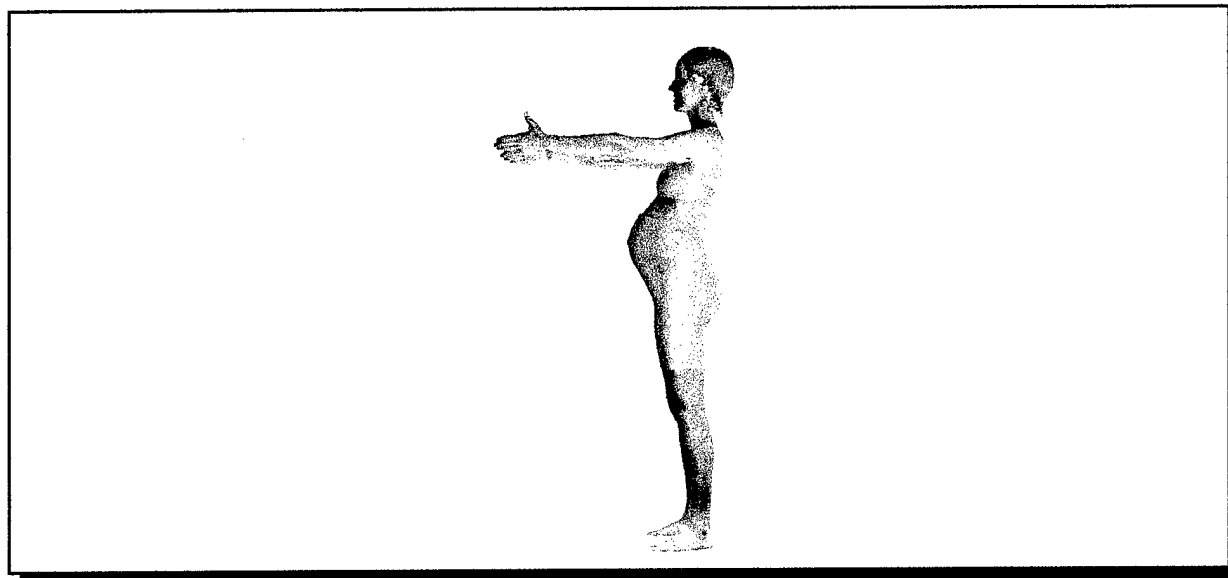
**FIGURE 2.1.8-1. Sitting Posture for Scanning**

This posture requires the subject to sit erect in a chair looking straight ahead with her head in the Frankfurt Plane. The scan technician aligns the feet with the hip and adjusts the knee angle to slightly greater than  $90^\circ$  ( $92^\circ$  or  $93^\circ$ ). The desired knee angle is achieved by raising or lowering the chair with the lever on the side of the chair. With some subjects, the chair is positioned as far down as possible, and the knee angle is still too great. The same foot boxes used for the traditional anthropometry are also used here to help align the knee to the desired angle. The subject holds her hands over her head in the midsagittal plane. Arms are abducted  $90^\circ$ , elbows flexed  $90^\circ$ , lower arms in the frontal plane, and fingers are spread with thumbs pointed toward the body. Shading is eliminated and this arm position is easily reproducible because of the right angle at the shoulder and elbow. This arm position also prevents any shading of the subject's abdominal area.

### 2.1.9 Standing

The standing posture requires the subject to stand erect on the platform looking straight ahead with the head in the Frankfurt Plane (see Figure 2.1.9-1). The feet are positioned shoulder width apart, aligned with the foot position stickers on the scanner platform. The arms are rotated to a forward reach in the horizontal plane of the shoulders. The hands are positioned shoulder width apart with the fingers together and the thumbs pointing upward. This position prevents shading of the abdominal area.

The entire data collection process is outlined in Table 2.1.9-1.



**FIGURE 2.1.9-1. Standing Posture for Scanning**

**TABLE 2.1.9-1.  
Data Collection Process**

1. Subject in-briefing (first session only).
2. Completion of Consent Forms (first session only).
3. Completion of Questionnaire Forms (first session and last session only).
4. Subject changes from street clothing into experiment PWS clothing for data collection procedure.
5. Location of the subject's anatomical landmarks:
  - a. Locate landmarks by visual inspection or by palpation (examination by touch);
  - b. Mark location with an eyeliner pencil and adhesive dots.
6. Collection of traditional measurements.
7. Selection of head covering:
  - a. Caps of different sizes are available;
  - b. Caps are necessary for the scanning process only.
8. Scan subject:
  - a. Standing posture--
    - (i) Check for error
    - (ii) Save scan if no error
    - (iii) Re-scan, if necessary
    - (iv) Save scan if no error
  - b. Sitting posture--
    - (i) Check for error
    - (ii) Save scan if no error
    - (iii) Re-scan, if necessary
    - (iv) Save scan if no error
9. De-prep subject:
  - a. Remove head covering;
  - b. Remove adhesive dots and eyeliner pencil marks which preserve locations of anatomical landmarks;
  - c. Subject changes back into street clothes.
10. Scheduling of next session.
11. Subject debriefing (final session only).

2.1.10 Demographics

There are currently 24 subjects participating in the study. The frequency distributions for the age of the subjects (at the initial session) and the race of the subjects are shown in Tables 2.1.10-1 and 2.1.10-2, respectively. A contingency table showing the distribution of the race of the baby's mother and father is shown in Table 2.1.10-3.

**TABLE 2.1.10-1.**  
**Age Distribution for Pregnant Women Study--1997**

AGE	FREQUENCY	PERCENT	CUMULATIVE FREQUENCY	CUMULATIVE PERCENT
21	1	4.2	1	4.2
23	1	4.2	2	8.3
24	2	8.3	4	16.7
25	2	8.3	6	25.0
26	3	12.5	9	37.5
27	5	20.8	14	58.3
28	2	8.3	16	66.7
29	2	8.3	18	75.0
32	1	4.2	19	79.2
34	3	12.5	22	91.7
35	1	4.2	23	95.8
37	1	4.2	24	100.0

**TABLE 2.1.10-2.**  
**Race Distribution for Pregnant Women Study--1997**

RACE OF BABY'S MOTHER	FREQUENCY	PERCENT	CUMULATIVE FREQUENCY	CUMULATIVE PERCENT
Black	1	4.2	1	4.2
Hispanic	2	8.3	3	12.5
Other	1	4.2	4	16.7
White	20	83.3	24	100.0

**TABLE 2.1.10-3.**  
**Contingency Table for Race of Baby's Mother and Father**

RACE OF BABY'S MOTHER	RACE OF BABY'S FATHER			TOTAL
	BLACK	OTHER	WHITE	
Black	0	0	1	1
Hispanic	0	1	1	2
Other	1	0	0	1
White	0	1	19	20
Total	1	2	21	24

Table 2.1.10-4, showing the number of previous live births and the current pregnancy number, indicates that two subjects had a previous miscarriage. This information may have an impact on the analysis at the end of the study.

**TABLE 2.1.10-4.**  
**Contingency Table for Current Pregnancy Number and Previous Live Births**

PREGNANCY NUMBER	PREVIOUS LIVE BIRTHS			TOTAL
	0	1	2	
1	17	0	0	17
2	1	4	0	5
3	0	0	1	1
4	0	0	1	1
Total	18	4	2	24

The statures and weights from the initial sessions of the subjects who are still enrolled in the study are shown in Figure 2.1.10-1. It is interesting to compare the pregnant subjects to past samples of female active-duty members. These comparisons are done using joint bivariate scatter plots of stature and weight. The first (Figure 2.1.10-2) compares the heights and weights of the Pregnant Women's Study subjects to the data collected from female active-duty Air Force members in 1968. Next, Figure 2.1.10-3 compares the data to that from the female U.S. Army *Anthropometric Survey (ANSUR)* from 1988. Finally, Figure 2.1.10-4 compares the study subject's heights and weights to those of the female active-duty Navy members collected in 1988. Each of these three figures shows that the female active-duty population is well represented by the sample participating in the Pregnant Women's Study.

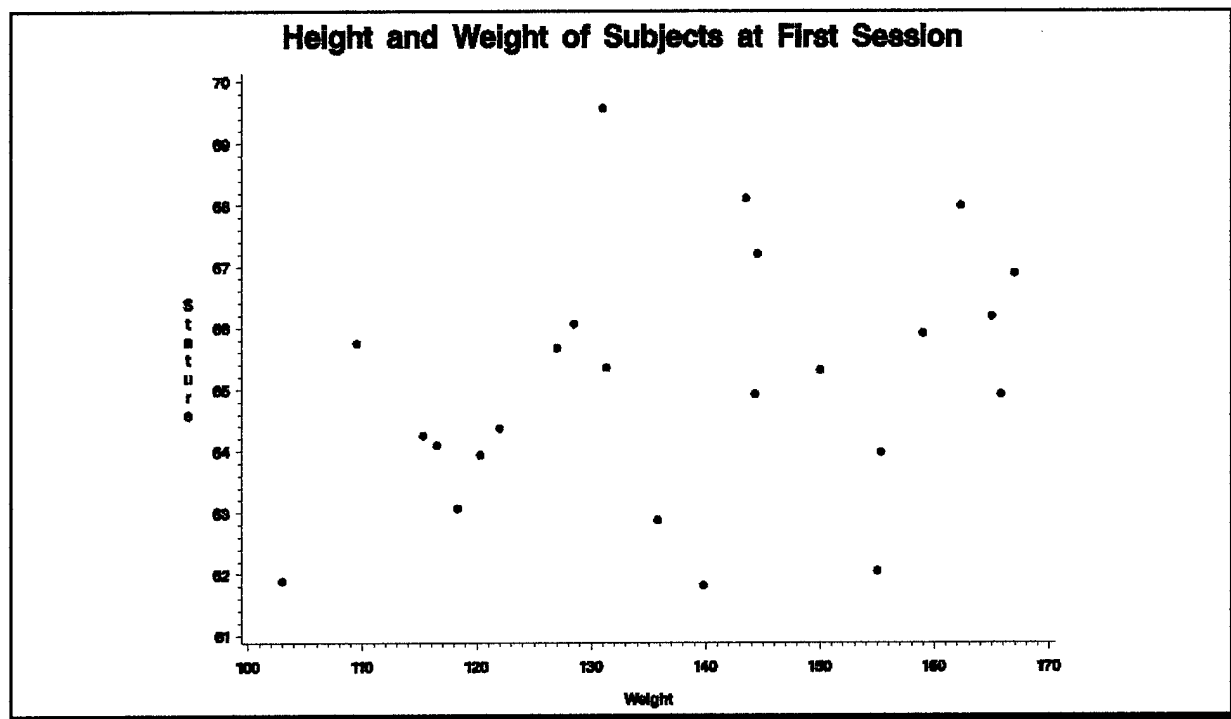


FIGURE 2.1.10-1. Height and Weight of Subjects at First Session

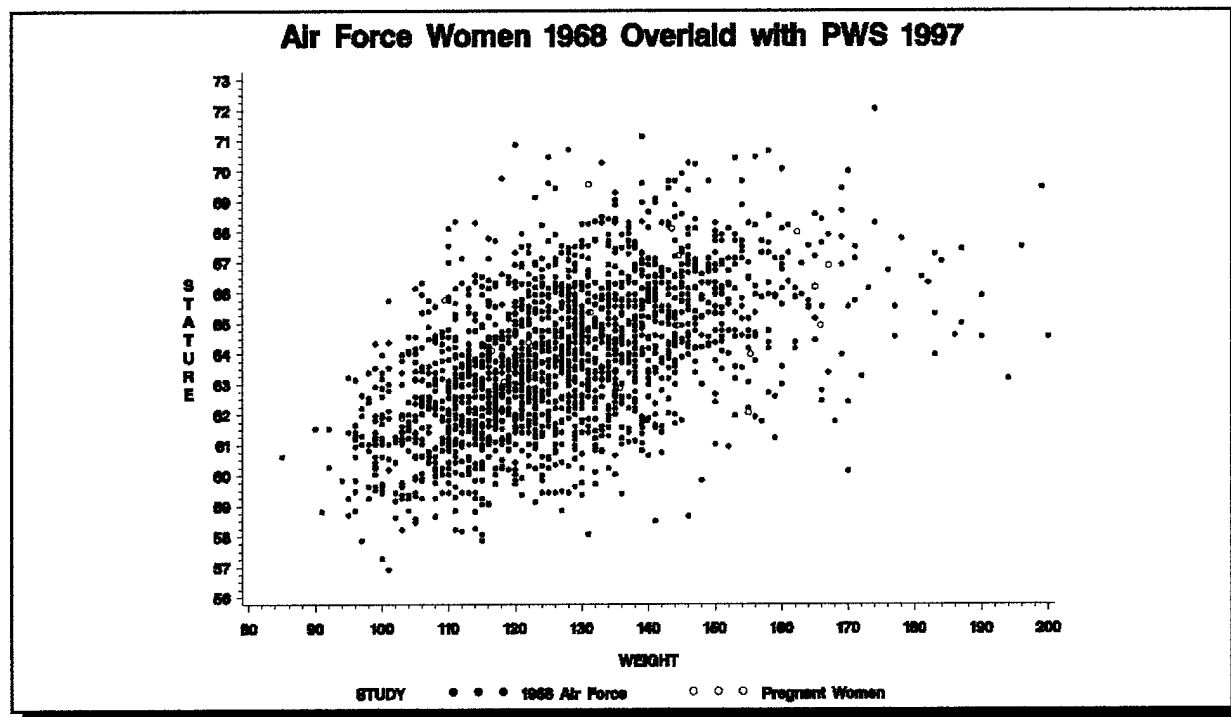


FIGURE 2.1.10-2. Air Force Women 1968 Overlaid with PWS 1997

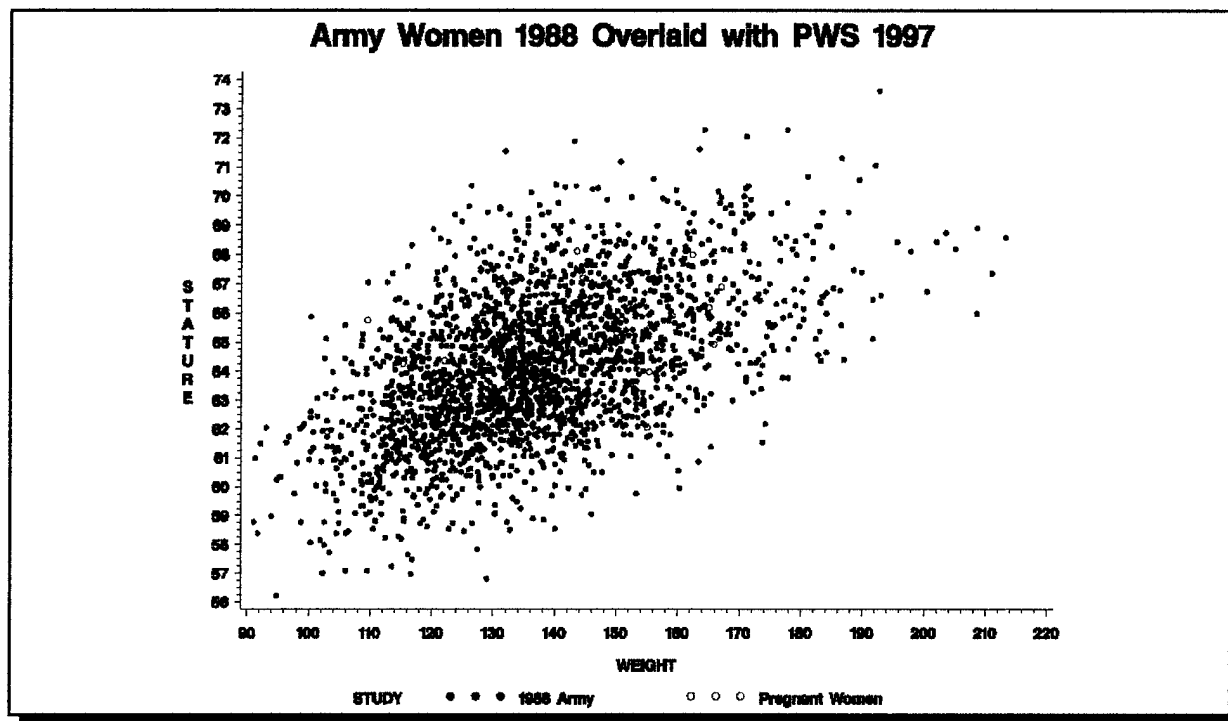


FIGURE 2.1.10-3. Army Women 1988 Overlaid with PWS 1997

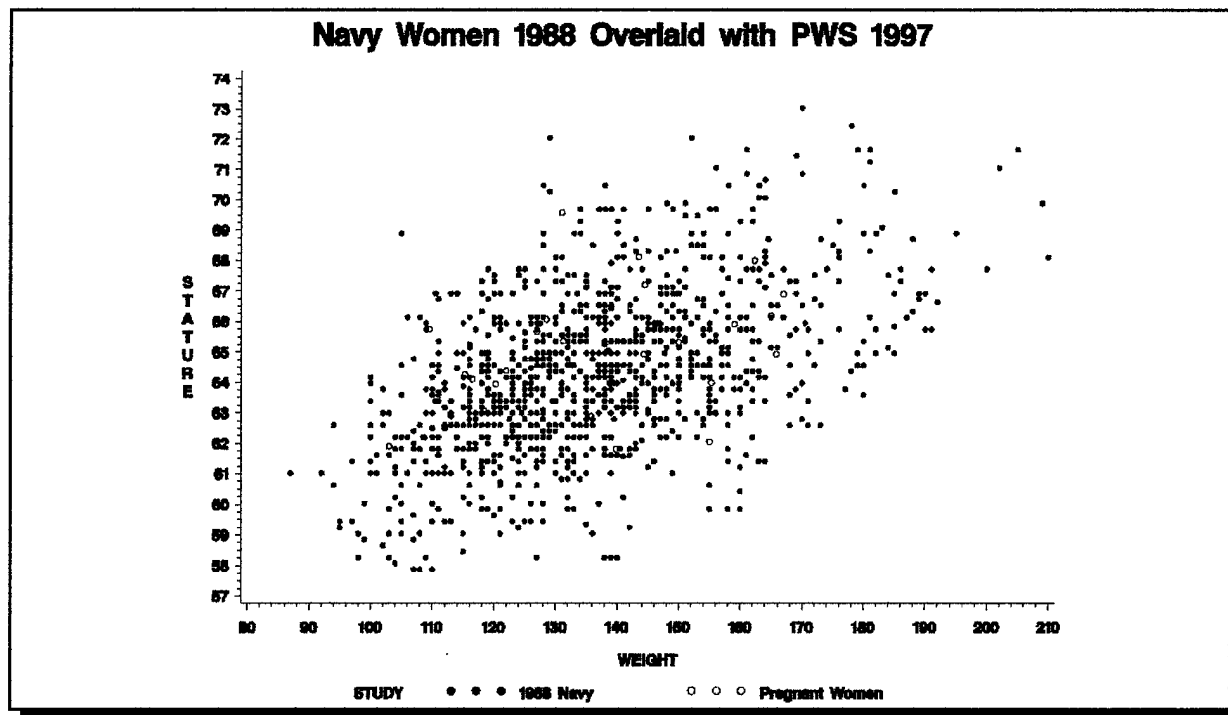


FIGURE 2.1.10-4. Navy Women 1988 Overlaid with PWS 1997

## 2.2 Results

Tables 2.2-1 through 2.2-4 provide summary statistics describing the anthropometry for the subjects by session. Weight is given in pounds and all other measurements are given in centimeters. Means of these measurements are given for the sake of completeness, but should not be used to make statistical inferences. The variation between subjects within a session is quite large, so inferences about the absolute measurements would not be useful.

**TABLE 2.2-1.**  
**Session 1 Summary**

MEASUREMENT	NUMBER IN GROUP	MEAN	STANDARD DEVIATION	MINIMUM	MAXIMUM
Cervicale Ht	24	141.808	4.6476	133.9	150.3
Chest Ht	24	118.958	3.8181	112.7	128.8
Chest Ht Below Bust	24	113.863	3.5208	108.0	122.5
Patella Top Ht	24	47.813	1.9479	44.3	51.9
Stature	24	165.329	5.1094	157.0	176.7
Substernale Ht	24	117.408	3.4154	111.8	127.1
Suprasternale Ht	24	134.488	4.2486	127.5	143.7
Tenth Rib Ht	24	107.354	3.3010	101.7	113.9
Thumbtip Reach	24	74.142	3.2308	68.4	80.3
Waist Ht, Omphalion	24	98.638	4.1525	89.6	106.4
Waist Ht, Preferred	24	100.750	4.4483	93.6	109.0
Weight	24	137.917	19.2286	103.0	167.0
Chest Breadth	24	28.475	1.8788	25.6	31.6
Chest Breadth Below Bust	24	26.717	1.4547	23.8	29.5
Chest Depth	24	23.071	2.1772	19.2	27.9
Chest Depth Below Bust	24	19.458	1.6049	16.4	22.5
Hip Breadth	24	36.446	2.4816	32.0	41.8
Waist Breadth, Omphalion	24	28.846	2.9906	22.9	35.3
Waist Breadth, Preferred	24	26.396	1.9354	23.0	29.8
Waist Depth, Omphalion	24	20.754	3.1358	15.7	27.2
Waist Depth, Preferred	24	19.592	2.4034	14.9	25.0
Ankle Circ	24	21.142	1.0421	19.1	23.1
Calf Circ	24	35.800	2.7592	31.7	41.0
Chest Circ	24	89.229	6.3441	79.9	101.5
Chest Circ Below Bust	24	76.342	4.5511	66.0	83.9
Foot Breadth	24	8.871	0.4112	8.2	9.5
Hip Circ	24	99.129	7.0087	86.6	111.5

MEASUREMENT	NUMBER IN GROUP	MEAN	STANDARD DEVIATION	MINIMUM	MAXIMUM
Thigh Circ, Proximal	24	58.254	5.5787	49.0	67.0
Waist Circ, Omphalion	24	81.238	9.3982	65.5	96.7
Waist Circ, Preferred	24	75.696	6.4873	64.2	87.8
Abdominal Extension Depth	24	22.554	2.9581	16.6	27.2
Buttock-Knee Lth	24	58.013	2.4330	53.4	61.6
Cervicale Ht, Sitting	24	64.221	2.3867	59.0	68.9
Hand Breadth	24	7.504	0.3210	7.0	8.3
Hip Breadth, Sitting	24	39.529	3.2577	34.6	45.7
Knee Ht, Sitting	24	50.888	1.7632	47.5	54.8
Sitting Ht	24	87.738	2.8814	82.1	92.6

**TABLE 2.2-2.**  
**Session 2 Summary**

MEASUREMENT	NUMBER IN GROUP	MEAN	STANDARD DEVIATION	MINIMUM	MAXIMUM
Cervicale Ht	20	141.870	4.8188	133.9	149.4
Chest Ht	20	119.565	4.2421	112.6	128.7
Chest Ht Below Bust	20	113.860	4.0688	106.6	122.3
Patella Top Ht	20	47.730	1.8632	44.2	51.4
Stature	20	165.790	5.5020	156.2	176.4
Substernale Ht	20	118.540	3.7442	112.0	126.4
Suprasternale Ht	20	134.890	4.5548	127.3	143.5
Tenth Rib Ht	20	108.465	4.1654	101.8	118.0
Thumbtip Reach	20	73.890	3.3731	69.6	80.8
Waist Ht, Omphalion	20	98.655	4.2437	89.3	107.4
Waist Ht, Preferred	20	102.335	5.1921	94.4	112.4
Weight	20	146.240	19.1850	110.0	174.8
Chest Breadth	20	29.315	2.0332	26.2	33.5
Chest Breadth Below Bust	20	27.010	1.5362	23.5	29.2
Chest Depth	20	23.785	2.0735	19.8	27.5
Chest Depth Below Bust	20	20.035	1.5819	16.4	23.4
Hip Breadth	20	36.970	2.4245	32.5	42.0
Waist Breadth, Omphalion	20	29.845	2.7729	26.1	36.0
Waist Breadth, Preferred	20	27.365	1.6388	23.7	30.4
Waist Depth, Omphalion	20	24.520	3.3923	19.2	32.0

MEASUREMENT	NUMBER IN GROUP	MEAN	STANDARD DEVIATION	MINIMUM	MAXIMUM
Waist Depth, Preferred	20	22.555	2.0457	18.3	26.1
Ankle Circ	20	21.105	1.0349	18.9	22.5
Calf Circ	20	36.040	2.8849	31.5	42.0
Chest Circ	20	92.220	5.7800	83.7	104.4
Chest Circ Below Bust	20	78.555	3.7723	70.8	84.9
Foot Breadth	20	8.655	0.3379	7.9	9.3
Hip Circ	20	101.145	5.8382	87.9	109.8
Thigh Circ, Proximal	20	59.365	4.8005	49.6	67.5
Waist Circ, Omphalion	20	90.030	9.5081	76.4	105.5
Waist Circ, Preferred	20	82.800	5.2788	71.7	91.0
Abdominal Extension Depth	20	26.415	3.1984	21.4	32.0
Buttock-Knee Lth	20	58.250	2.2714	53.3	62.3
Cervicale Ht, Sitting	20	64.430	2.3335	59.8	69.0
Hand Breadth	20	7.510	0.3740	7.0	8.2
Hip Breadth, Sitting	20	40.340	3.0036	35.1	45.6
Knee Ht, Sitting	20	50.995	1.8681	47.7	54.8
Sitting Ht	20	88.340	2.9213	82.7	92.8

**TABLE 2.2-3.**  
**Session 3 Summary**

MEASUREMENT	NUMBER IN GROUP	MEAN	STANDARD DEVIATION	MINIMUM	MAXIMUM
Cervicale Ht	10	142.15	4.4185	134.9	149.9
Chest Ht	10	121.05	4.4613	115.6	129.7
Chest Ht Below Bust	10	114.83	4.0817	110.2	123.0
Patella Top Ht	10	48.16	1.7545	46.0	51.9
Stature	10	166.03	5.1915	157.1	176.6
Substernale Ht	10	119.53	4.0489	114.8	127.0
Suprasternale Ht	10	135.42	4.5301	128.3	144.3
Tenth Rib Ht	10	110.31	3.2385	106.5	117.4
Thumbtip Reach	10	73.69	2.8938	70.2	78.4
Waist Ht, Omphalion	10	98.58	3.5380	93.2	106.2
Waist Ht, Preferred	10	105.43	4.3349	97.7	114.2
Weight	10	155.74	17.3107	125.5	181.3
Chest Breadth	10	29.96	1.8204	27.0	33.2

MEASUREMENT	NUMBER IN GROUP	MEAN	STANDARD DEVIATION	MINIMUM	MAXIMUM
Chest Breadth Below Bust	10	27.84	1.8167	24.5	30.3
Chest Depth	10	23.79	1.7149	21.6	26.7
Chest Depth Below Bust	10	20.54	0.9789	19.2	22.4
Hip Breadth	10	37.93	2.9223	33.2	43.8
Waist Breadth, Omphalion	10	30.86	2.6243	27.0	36.1
Waist Breadth, Preferred	10	28.00	1.5202	26.0	30.2
Waist Depth, Omphalion	10	28.12	2.9165	23.9	33.9
Waist Depth, Preferred	10	24.99	1.9307	21.6	27.6
Ankle Circ	10	21.62	0.9566	20.0	23.0
Calf Circ	10	37.19	3.0362	32.3	42.3
Chest Circ	10	93.15	5.6600	85.0	102.3
Chest Circ Below Bust	10	79.90	3.4631	75.5	86.4
Foot Breadth	10	8.81	0.4977	8.0	9.7
Hip Circ	10	103.74	7.0684	90.7	114.4
Thigh Circ, Proximal	10	61.29	4.5708	52.2	69.2
Waist Circ, Omphalion	10	97.64	6.6390	84.3	105.1
Waist Circ, Preferred	10	87.80	4.7607	78.2	93.2
Abdominal Extension Depth	10	29.42	2.8185	25.5	34.9
Buttock-Knee Lth	10	59.46	1.3159	57.0	61.1
Cervicale Ht, Sitting	10	64.26	2.0095	59.7	67.3
Hand Breadth	10	7.66	0.4006	7.0	8.4
Hip Breadth, Sitting	10	41.81	3.0534	36.9	47.2
Knee Ht, Sitting	10	51.54	1.5925	49.5	55.1
Sitting Ht	10	88.34	2.9703	82.2	92.4

**TABLE 2.2-4.**  
**Session 4 Summary**

MEASUREMENT	NUMBER IN GROUP	MEAN	STANDARD DEVIATION	MINIMUM	MAXIMUM
Cervicale Ht	6	144.217	2.9444	142.1	149.7
Chest Ht	6	122.600	3.5777	120.3	129.8
Chest Ht Below Bust	6	116.800	3.2882	114.4	123.2
Patella Top Ht	6	48.567	1.8811	46.8	51.9
Stature	6	168.333	4.0579	164.7	176.3
Substernale Ht	6	121.483	2.7448	118.5	126.7

MEASUREMENT	NUMBER IN GROUP	MEAN	STANDARD DEVIATION	MINIMUM	MAXIMUM
Suprasternale Ht	6	137.450	3.2880	134.7	143.8
Tenth Rib Ht	6	111.900	3.1553	109.9	118.2
Thumbtip Reach	6	73.517	3.0630	69.8	77.3
Waist Ht, Omphalion	6	99.550	3.2611	95.6	105.4
Waist Ht, Preferred	6	105.133	7.6842	94.9	118.0
Weight	6	156.733	18.9615	127.5	184.3
Chest Breadth	6	29.967	2.2250	27.2	33.5
Chest Breadth Below Bust	6	27.833	1.8283	24.8	30.3
Chest Depth	6	24.217	1.5052	22.0	26.0
Chest Depth Below Bust	6	21.317	0.7885	20.2	22.1
Hip Breadth	6	36.700	2.2262	34.1	40.8
Waist Breadth, Omphalion	6	31.067	2.7739	26.8	35.4
Waist Breadth, Preferred	6	28.550	1.1895	27.2	30.0
Waist Depth, Omphalion	6	29.500	2.2663	25.8	32.4
Waist Depth, Preferred	6	26.900	1.7731	24.1	28.8
Ankle Circ	6	21.200	1.1100	20.0	23.0
Calf Circ	6	36.600	2.7386	32.8	40.2
Chest Circ	6	93.683	6.1033	85.1	103.3
Chest Circ Below Bust	6	80.800	3.9633	75.2	84.8
Foot Breadth	6	9.050	0.4037	8.5	9.6
Hip Circ	6	101.917	6.9675	92.4	112.6
Thigh Circ, Proximal	6	59.817	5.7534	52.6	69.5
Waist Circ, Omphalion	6	100.267	8.3570	85.6	109.0
Waist Circ, Preferred	6	90.217	4.6469	84.1	96.5
Abdominal Extension Depth	6	30.233	2.4897	26.0	32.8
Buttock-Knee Lth	6	60.050	1.1726	58.5	61.8
Cervicale Ht, Sitting	6	64.600	0.8649	63.4	65.9
Hand Breadth	6	7.583	0.3971	7.1	8.2
Hip Breadth, Sitting	6	41.033	3.1284	36.9	45.9
Knee Ht, Sitting	6	52.050	1.7352	50.5	55.2
Sitting Ht	6	88.800	2.1762	86.2	91.9

Summary statistics for the changes in measurements between one session and the next appear in Tables 2.2-5 through 2.2-7. The changes from Session 1 to Session 2 do not merit a great deal of emphasis. Although the initial sessions were scheduled after the subjects found out about their pregnancies and before visible physical changes had occurred, the number of weeks into pregnancy were not consistent between subjects. However, follow-ups sessions were scheduled according to weeks into pregnancy with very little variation occurring between subjects.

**TABLE 2.2-5.**  
**Changes from Session 1 to Session 2**

MEASUREMENT	NUMBER IN GROUP	MEAN CHANGE	STANDARD DEVIATION	MAXIMUM CHANGE	MINIMUM CHANGE
Cervicale Ht	20	-0.130	0.60793	1.4	-1.2
Chest Ht	20	0.270	1.24904	2.4	-2.3
Chest Ht Below Bust	20	-0.335	0.90454	1.3	-2.4
Patella Top Ht	20	-0.100	0.60263	1.3	-1.1
Stature	20	0.050	0.52965	0.9	-0.8
Substernale Ht	20	0.820	1.22758	3.3	-0.8
Suprasternale Ht	20	0.055	0.56983	1.3	-1.1
Tenth Rib Ht	20	0.905	1.53331	4.1	-1.5
Thumbtip Reach	20	0.090	1.19071	2.9	-2.5
Waist Ht, Omphalion	20	-0.200	0.78405	1.4	-1.4
Waist Ht, Preferred	20	1.295	2.92583	6.8	-4.2
Weight	20	9.370	4.40659	18.5	2.3
Chest Breadth	20	0.840	0.82168	2.2	-0.4
Chest Breadth Below Bust	20	0.270	0.47914	1.2	-0.7
Chest Depth	20	0.875	0.65283	2.3	-0.2
Chest Depth Below Bust	20	0.605	0.67158	1.4	-1.4
Hip Breadth	20	0.795	0.73160	2.2	-0.5
Waist Breadth, Omphalion	20	1.185	1.41580	4.8	-1.2
Waist Breadth, Preferred	20	1.060	1.79953	5.1	-2.1
Waist Depth, Omphalion	20	3.925	1.74020	6.5	0.4
Waist Depth, Preferred	20	3.085	1.70549	5.7	0.0
Ankle Circ	20	-0.055	0.70746	1.6	-1.7
Calf Circ	20	0.315	0.51532	1.1	-0.6
Chest Circ	20	3.430	2.34433	8.7	-0.2
Chest Circ Below Bust	20	2.425	2.05628	7.8	-0.3
Foot Breadth	20	-0.250	0.27048	0.2	-0.9
Hip Circ	20	2.635	2.33537	6.6	-3.1

MEASUREMENT	NUMBER IN GROUP	MEAN CHANGE	STANDARD DEVIATION	MAXIMUM CHANGE	MINIMUM CHANGE
Thigh Circ, Proximal	20	1.625	1.56100	3.9	-2.6
Waist Circ, Omphalion	20	9.600	4.38658	17.2	2.0
Waist Circ, Preferred	20	7.455	5.32348	19.5	0.0
Abdominal Extension Depth	20	3.875	1.64441	6.4	-0.5
Buttock-Knee Lth	20	0.255	0.62448	1.4	-0.8
Cervicale Ht, Sitting	20	0.055	0.73304	1.8	-1.9
Hand Breadth	20	-0.010	0.17741	0.3	-0.4
Hip Breadth, Sitting	20	1.065	0.88572	2.7	-0.3
Knee Ht, Sitting	20	0.090	0.49937	1.2	-0.6
Sitting Ht	20	0.225	0.35818	0.8	-0.6

**TABLE 2.2-6.**  
**Changes from Session 2 to Session 3**

MEASUREMENT	NUMBER IN GROUP	MEAN CHANGE	STANDARD DEVIATION	MAXIMUM CHANGE	MINIMUM CHANGE
Cervicale Ht	10	-0.08	0.40497	0.8	-0.6
Chest Ht	10	0.73	1.17384	2.5	-0.8
Chest Ht Below Bust	10	0.14	0.70111	1.3	-0.5
Patella Top Ht	10	0.42	0.78712	1.7	-0.6
Stature	10	-0.22	0.37947	0.2	-1.1
Substernale Ht	10	0.83	0.96385	2.0	-0.5
Suprasternale Ht	10	0.14	0.52957	1.1	-0.7
Tenth Rib Ht	10	1.82	1.50170	5.1	-0.6
Thumbtip Reach	10	0.38	1.41798	3.5	-0.9
Waist Ht, Omphalion	10	-0.28	1.64708	3.5	-3.0
Waist Ht, Preferred	10	2.64	4.47938	10.0	-3.8
Weight	10	8.90	3.03425	12.0	3.0
Chest Breadth	10	1.06	0.90823	3.2	-0.2
Chest Breadth Below Bust	10	0.98	0.72080	2.3	-0.1
Chest Depth	10	0.79	0.73854	2.3	-0.2
Chest Depth Below Bust	10	1.05	0.93956	2.8	-0.6
Hip Breadth	10	0.92	0.88669	2.0	-0.5
Waist Breadth, Omphalion	10	1.45	0.70277	2.4	0.3
Waist Breadth, Preferred	10	0.91	1.67958	2.3	-3.4
Waist Depth, Omphalion	10	3.63	1.63643	6.8	1.8

MEASUREMENT	NUMBER IN GROUP	MEAN CHANGE	STANDARD DEVIATION	MAXIMUM CHANGE	MINIMUM CHANGE
Waist Depth, Preferred	10	2.88	1.74343	6.0	0.0
Ankle Circ	10	0.30	0.62361	1.6	-0.7
Calf Circ	10	0.66	0.57966	1.5	-0.2
Chest Circ	10	2.57	1.47426	4.5	0.4
Chest Circ Below Bust	10	2.02	1.31555	4.7	0.2
Foot Breadth	10	0.06	0.35024	0.4	-0.6
Hip Circ	10	2.32	1.70867	6.0	0.3
Thigh Circ, Proximal	10	1.39	1.04929	2.7	-0.1
Waist Circ, Omphalion	10	8.51	4.35825	16.6	2.5
Waist Circ, Preferred	10	5.90	5.44141	13.3	-6.7
Abdominal Extension Depth	10	3.41	1.06714	5.9	2.3
Buttock-Knee Lth	10	0.91	0.62796	2.1	0.1
Cervicale Ht, Sitting	10	-0.10	0.31269	0.5	-0.5
Hand Breadth	10	0.19	0.15239	0.4	0.0
Hip Breadth, Sitting	10	1.25	0.65362	2.1	0.0
Knee Ht, Sitting	10	0.52	0.44920	1.1	-0.2
Sitting Ht	10	-0.07	0.41110	0.5	-0.6

**TABLE 2.2-7.**  
**Changes from Session 3 to Session 4**

MEASUREMENT	NUMBER IN GROUP	MEAN CHANGE	STANDARD DEVIATION	MAXIMUM CHANGE	MINIMUM CHANGE
Cervicale Ht	5	0.18	0.40249	0.6	-0.2
Chest Ht	5	0.32	1.18617	2.2	-1.0
Chest Ht Below Bust	5	0.36	0.50299	1.2	-0.1
Patella Top Ht	5	-0.36	0.67305	0.6	-1.1
Stature	5	-0.10	0.24495	0.3	-0.3
Substernale Ht	5	-0.18	2.35521	2.6	-3.9
Suprasternale Ht	5	-0.16	0.45607	0.3	-0.7
Tenth Rib Ht	5	0.36	0.55045	1.1	-0.1
Thumbtip Reach	5	-0.36	0.98641	0.9	-1.4
Waist Ht, Omphalion	5	-0.54	0.93968	1.1	-1.2
Waist Ht, Preferred	5	0.00	3.78418	3.8	-5.0
Weight	5	2.96	0.63875	3.8	2.0
Chest Breadth	5	0.20	0.48477	0.7	-0.6

MEASUREMENT	NUMBER IN GROUP	MEAN CHANGE	STANDARD DEVIATION	MAXIMUM CHANGE	MINIMUM CHANGE
Chest Breadth Below Bust	5	0.12	0.26833	0.3	-0.3
Chest Depth	5	0.32	0.50695	0.9	-0.2
Chest Depth Below Bust	5	0.54	0.69857	1.5	-0.3
Hip Breadth	5	0.18	0.50200	0.9	-0.3
Waist Breadth, Omphalion	5	0.74	0.64265	1.5	-0.2
Waist Breadth, Preferred	5	0.46	1.07145	2.0	-0.8
Waist Depth, Omphalion	5	2.08	0.38987	2.5	1.5
Waist Depth, Preferred	5	1.36	1.88892	3.8	-1.4
Ankle Circ	5	-0.14	0.29665	0.2	-0.5
Calf Circ	5	-0.10	0.73485	0.5	-1.3
Chest Circ	5	0.10	1.25100	1.3	-1.9
Chest Circ Below Bust	5	0.10	1.57162	2.4	-1.6
Foot Breadth	5	0.58	0.22804	0.9	0.3
Hip Circ	5	0.94	0.52249	1.7	0.4
Thigh Circ, Proximal	5	-0.04	0.55946	0.4	-0.7
Waist Circ, Omphalion	5	3.92	1.94088	6.0	1.3
Waist Circ, Preferred	5	0.32	3.60236	5.3	-4.8
Abdominal Extension Depth	5	1.38	1.57385	3.1	-0.5
Buttock-Knee Lth	5	0.50	0.81548	1.5	-0.6
Cervicale Ht, Sitting	5	0.08	0.21679	0.2	-0.3
Hand Breadth	5	0.02	0.14832	0.2	-0.2
Hip Breadth, Sitting	5	0.16	0.20736	0.4	-0.1
Knee Ht, Sitting	5	-0.16	0.39749	0.3	-0.7
Sitting Ht	5	-0.28	0.69785	0.3	-1.4

### 2.2.1 Statistical Analysis

**Euclidean Distance Matrix Analysis (EDMA)** is a coordinate-free approach to the analysis of form through the use of landmarks. EDMA looks at the change in the relative Euclidean distances between all landmarks. (Due to the assumption of homogeneity, only those landmarks which are visible and common to all subjects and scans can be used.) For EDMA, the statistical analyst creates a matrix of distances between all landmarks, called a form matrix, for each scan. Thus, assuming no sessions were missed, there will be six form matrices for each subject. Next, the analyst computes a **form difference matrix (FDM)** by taking the ratio of each element of one form matrix to another, so the differences in distances between sessions can be considered as ratios. Again, assuming no sessions were missed, each subject will have 15 FDMs. If the FDM is "almost" a matrix of 1s, then the two forms are equal. If the FDM is "almost" a matrix of constants, then the two shapes are equal. The FDMs for all subjects

may be averaged together by sessions to determine an average or mean change. These average FDMs can then be tested to determine if the forms or shapes change in a consistent manner. Currently, there is only one subject who has completed the study. The following paragraph illustrates EDMA using this subject as an example.

### 2.2.1.1 EDMA Example

Using the scanned data, the three-dimensional location of the landmarks was recorded. Twenty-three landmarks were visible and common to all scans for the subject. A list of the 23 landmarks appears in Table 2.2.1.1-1 below. (The ratios which were calculated for the subject are presented in Appendix F.)

**TABLE 2.2.1.1-1.  
Landmarks Used in EDMA**

LANDMARK NUMBER	LANDMARK NAME
1	Cervicale
2	Cervicale -10 (10 cm below Cervicale)
3	Cervicale -20 (20 cm below Cervicale)
4	Cervicale -30 (30 cm below Cervicale)
5	Cervicale -40 (40 cm below Cervicale)
6	PSIS left
7	PSIS right
8	Buttock Point back
9	Infraorbitale left
10	Infraorbitale right
11	Bustpoint left
12	Bustpoint right
13	Substernale
14	Tenth Rib left
15	Tenth Rib right
16	Waist Level Omphalion
17	Waist Level Preferred
18	ASIS left
19	ASIS right
20	Suprapatella left
21	Suprapatella right
22	Buttock Point left
23	Buttock Point right

Of the 23 landmarks, Infraorbitale left (9) and Infraorbitale right (10) were considered unnecessary for the analysis. Also, landmarks which are measured down the spine from Cervicale (landmarks 2-5) were not used. When distances are calculated from a landmark near the midsagittal plane to landmarks which occur on both the left and right, symmetry in the distances and ratios are expected to be seen. At this point in the study, it is difficult to determine what is a significant or critical value of the ratios. For the sake of illustration, a change is considered significant if it results in a ratio smaller than 0.80 or larger than 1.20. Once all of the subjects have completed the study, critical values for the ratios will be reviewed and revised.

Using the critical values above, several ratios indicate that no significant changes occurred in those distances during the study. Distances where no change occurred include:

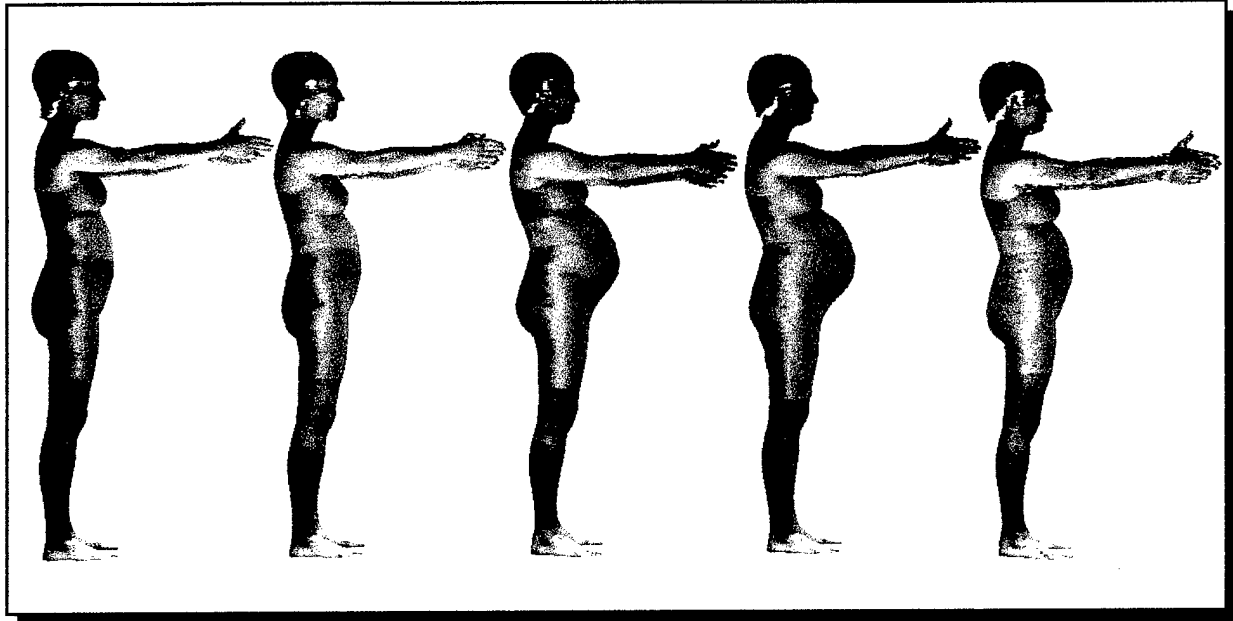
- Cervicale to Bustpoint left (1 to 11),
- Cervicale to Bustpoint right (1 to 12),
- Cervicale to Substernale (1 to 13),
- Substernale to Tenth Rib left (13 to 14),
- Substernale to Tenth Rib right (13 to 15),
- Substernale to ASIS left (13 to 16), and
- Substernale to ASIS right (13 to 17).

Some interesting and significant changes occurred between Substernale and Waist Level Omphalion (13 to 16), and Substernale and Waist Level Preferred (13 to 17). From the first session through the fifth, these distances became smaller, indicating the swelling of the abdomen and upward movement of the waist level. However, from the fifth (last session before delivery) session to the six (post-delivery) session, the waist levels moved downward dramatically. It is expected that the distances from PSIS right to PSIS left (6 to 7) will change over the course of the pregnancy, and the ratios confirm that. However, the ratios indicate that at the sixth session, the distance had returned to what it was at the time of the second session.

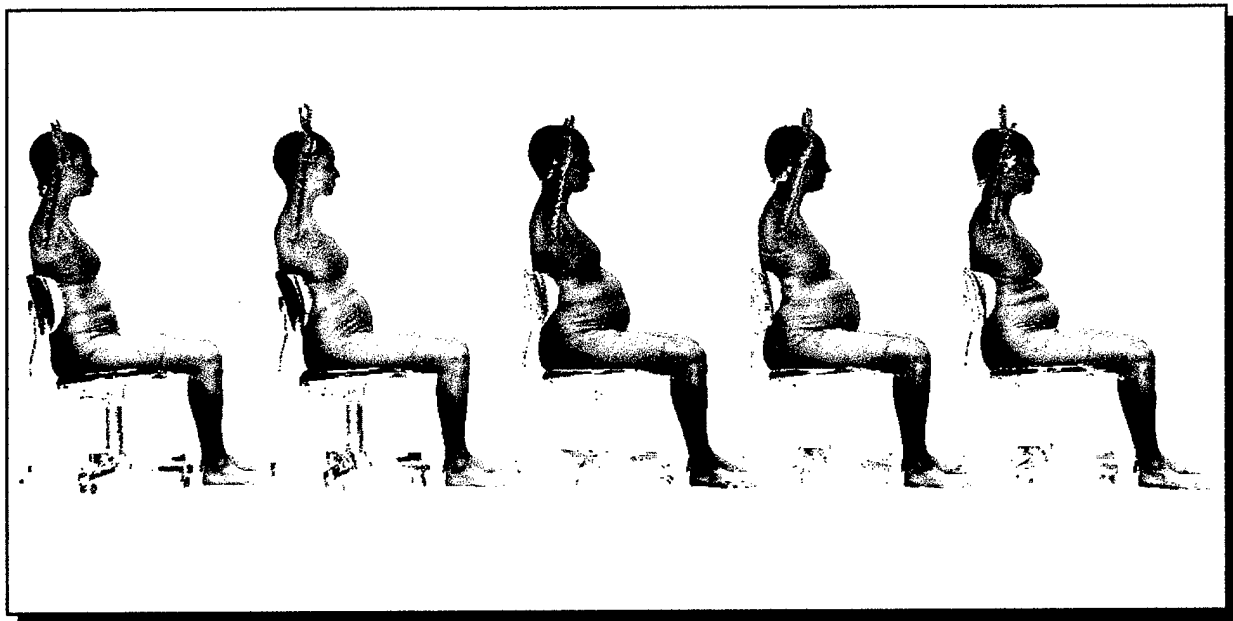
### 2.3 Findings

As the subjects are followed throughout pregnancy, women struggle to adjust to the extra size and weight of the developing fetus. Each stage of pregnancy presents a new size and shape change, so it is very difficult for women to adjust to their constantly changing bodies.

A pregnant woman's body assumes an entirely different shape in the standing position than in the seated position. Figures 2.3-1 and 2.3-2, two series of scans for the same subject in both the standing and sitting posture, show the differences in shape form.



**FIGURE 2.5-1. Series of Scans for the Same Subject in the Standing Posture<sup>1</sup>**

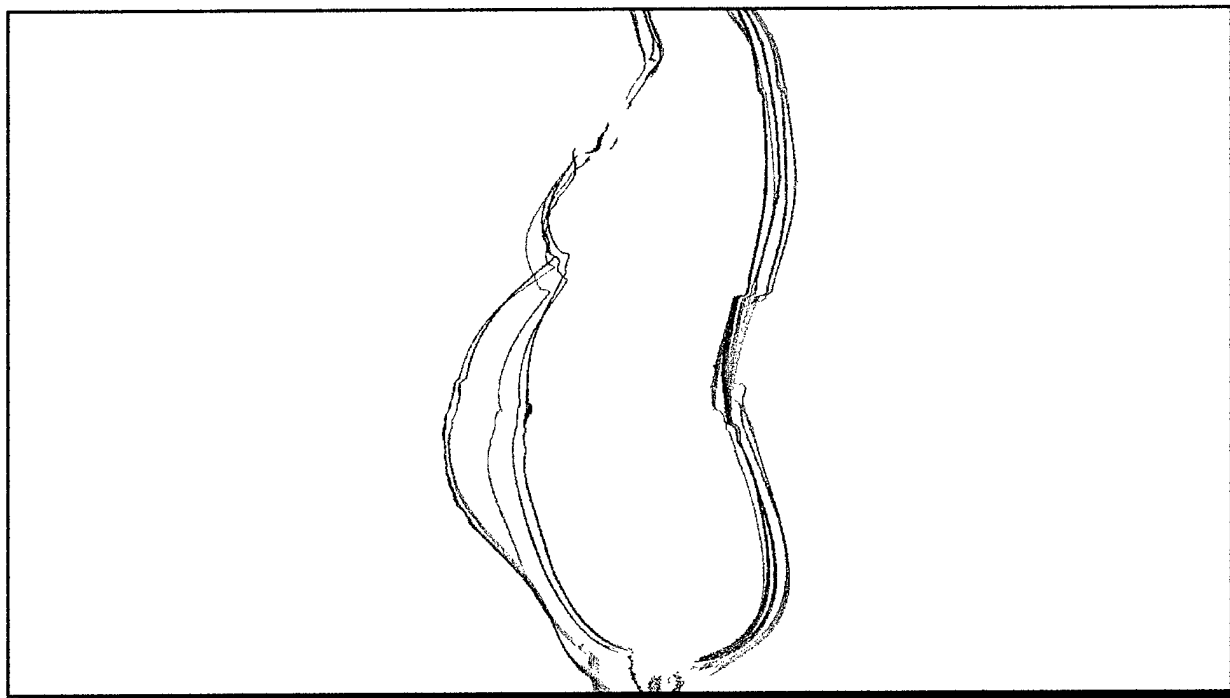


**FIGURE 2.3-2. Series of Scans for the Same Subject in the Seated Posture**

<sup>1</sup> For Figures 2.3-1. And 2.3-2, from left to right: first scan - 16 weeks, second scan - 20 weeks, third scan - missed due to problems with the Whole Body Scanner, fourth scan - 32 weeks, fifth scan - 38 weeks, and the sixth scan was completed two weeks after delivery. Scans 1 and 2 are less colorful than Scans 4, 5, and 6. During the time between Scan 1 and Scan 4, technicians installed color filters on the Cyberware WB4 Whole Body Scanner *Change Coupled Device (CCD)* camera, which results in a more vivid scan.

### 2.3.1 Postural Changes

During pregnancy, the magnitude and distribution of loads acting on the spine change dramatically. The increasing bulkiness of the anterior abdomen changes the woman's center of gravity, and many women develop an accentuated lumbar curvature (lordosis) during the last few months of pregnancy. This posture change associated with pregnancy is clearly seen in Figure 2.3-3, which shows five superimposed, 3-D whole body scans of one subject throughout pregnancy.



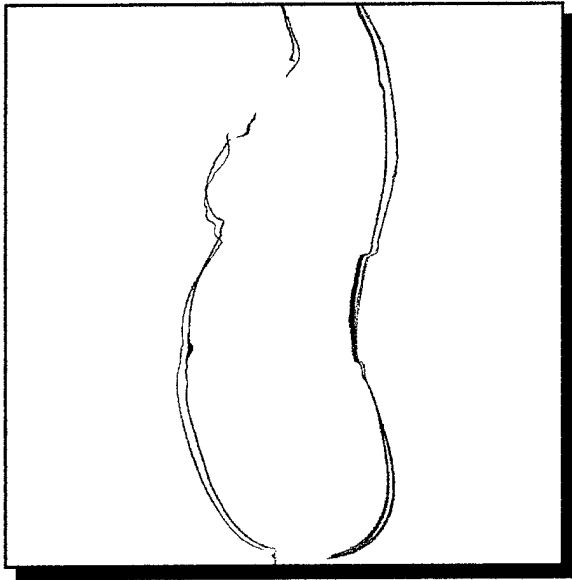
**FIGURE 2.3-3. Scans 1, 2, 4, 5, and 6 Superimposed <sup>2</sup>**

Figure 2.4-3 shows that the trunk angle is increased. This increased trunk angle, together with the increased weight of the pregnant abdomen, increases the torque on the lumbosacral junction, requiring an increase in the developed muscle tension (Nicholls and Grieve, 1992). This change in posture may be associated with low-back pain during pregnancy, experienced by an estimated 49% of women at some point during their pregnancy (Moore, Dumas, and Ried, 1990).

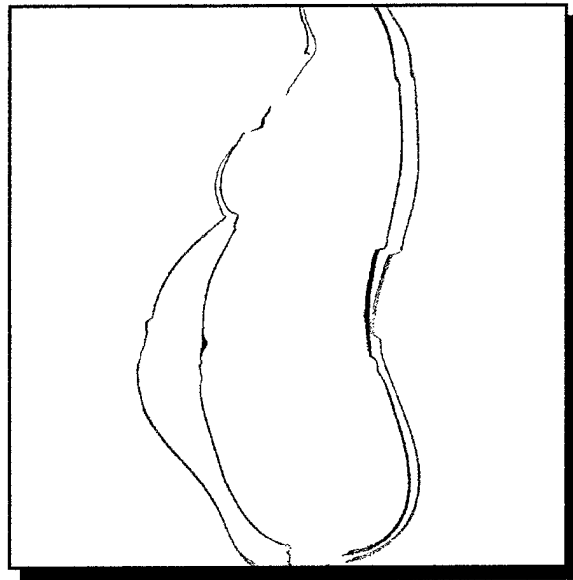
When the first scan of this subject was superimposed with the second, fourth, and fifth scans individually in Figures 2.3-4 through 2.3-6, a marked increase in the angle of trunk inclination is clear. As the pregnancy progresses from 16 weeks to 38 weeks, posture changes dramatically. Figure 2.3-7 shows the change of declination of the spine for a subject two weeks after delivery compared to 38 weeks pregnant.

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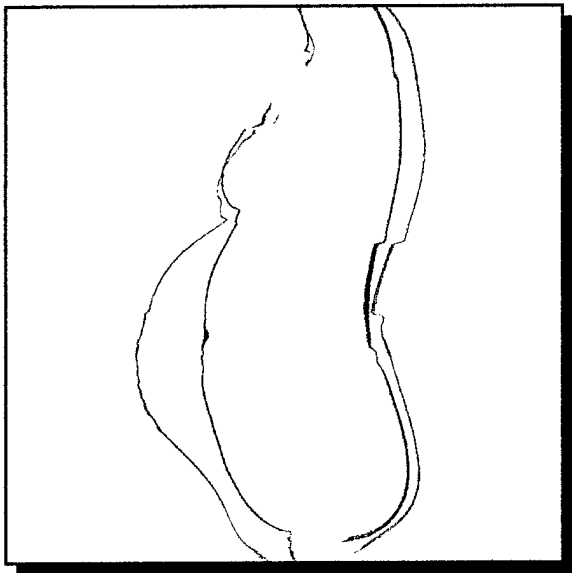
<sup>2</sup> Scan 1 (red, 16 weeks), Scan 2 (purple, 20 weeks), Scan 4 (yellow, 32 weeks), Scan 5 (blue, 38 weeks), and Scan 6 (grey, 2 weeks after delivery) superimposed for Subject #4.



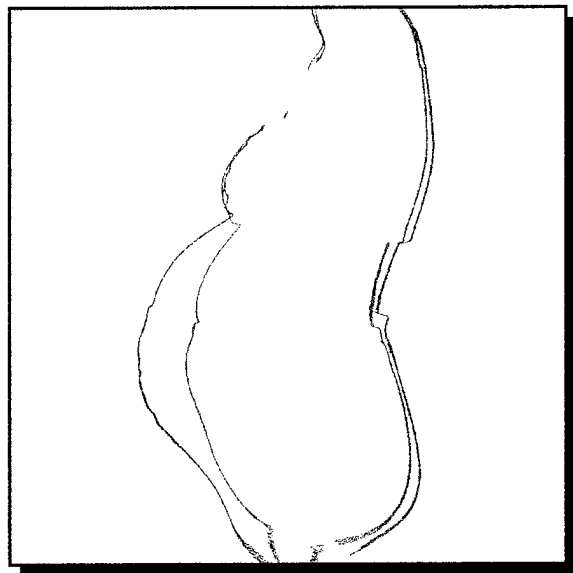
**FIGURE 2.3-4. Scan 1 (red, 16 weeks)  
Superimposed with Scan 2  
(purple, 20 weeks) for Subject #4**



**FIGURE 2.3-5. Scan 1 (red, 16 weeks)  
Superimposed with Scan 4  
(yellow, 32 weeks) for Subject #4**



**FIGURE 2.3-6. Scan 1 (red, 16 weeks)  
Superimposed with Scan 5  
(blue, 38 weeks) for Subject #4**



**FIGURE 2.3-7. Scan 5 (blue, 38 weeks)  
Superimposed with Scan 6  
(grey, 2 weeks after delivery) for Subject #4**

### 2.3.2 Preliminary Tenth Rib Changes

Pregnancy is a time of rapid biological change and all bodily organs and systems are affected by the process (Bullock, J. E., Gwendolen, J. A., and Bullock, M. I., 1987). The uterus starts as a fist-sized organ and grows to occupy most of the pelvic cavity by 16 weeks. As pregnancy continues, the uterus pushes higher and higher into the abdominal cavity, exerting increasing pressure on both abdominal and pelvic organs. As birth nears, the uterus reaches the level of the xiphoid process and occupies the bulk of the abdominal cavity. The crowded abdominal organs press superiorly against the diaphragm which intrudes on the thoracic cavity. As a result, the ribs flare, causing the thorax to widen (Marieb, 1992).

Twelve pairs of ribs form the sides of the thoracic cage. All attach posteriorly to the thoracic vertebrae and then curve downward and forward toward the anterior body surface. The upper seven rib pairs attach directly to the sternum by individual costal cartilages. The remaining five pairs of ribs attach indirectly to the sternum or lack a sternal attachment entirely. In fact, rib pairs 8-10 attach to the sternum indirectly by joining to each other via the costal cartilages immediately above (Marieb, 1992). The tenth rib is the lowest point on the inferior border of the tenth (lowest palpable) rib. Rib pairs 11 and 12 are called floating ribs because they have no anterior attachments (Marieb, 1992). Figure 2.3.2-1 charts tenth rib height (cm) by session number. For many subjects, tenth rib height increased from the first measurement session to the third measurement session. Included in this chart are three sessions instead of six sessions because the data collection is still in progress. This increase in height may be caused by the movement or flaring of the ribs, which could be expanding outward and upward to help accommodate the growing fetus.

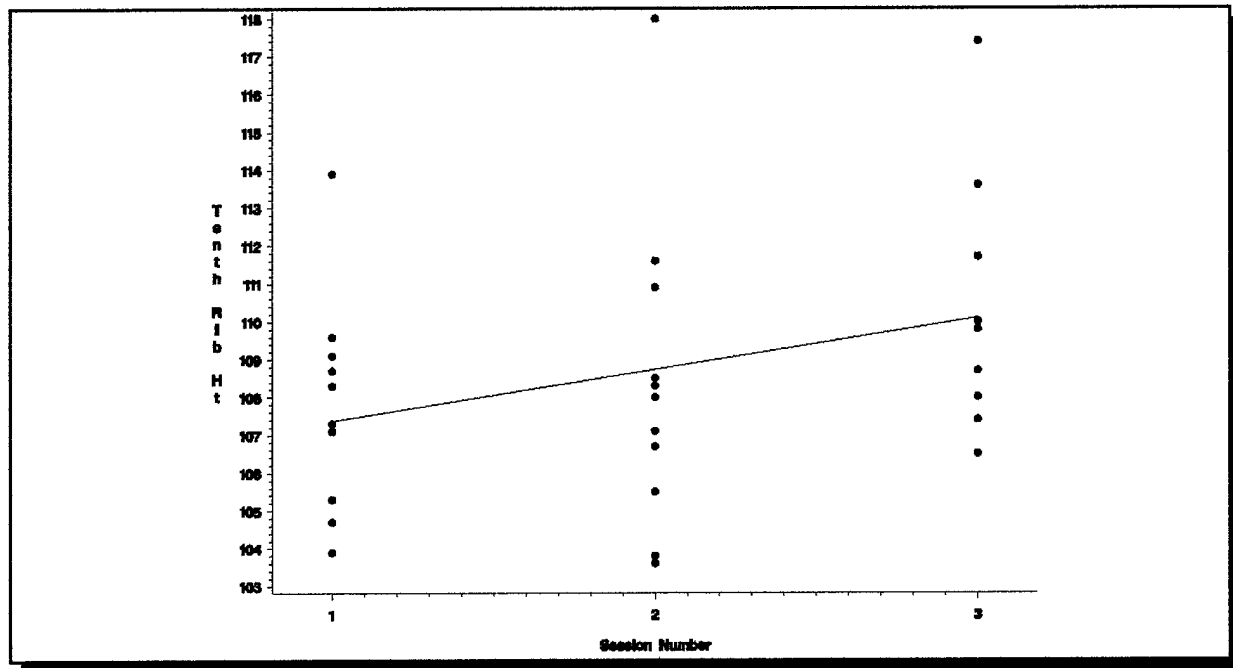


FIGURE 2.3.2-1. Tenth Rib Height (cm) by Session Number

## 2.4 Discussions

For many subjects, the shape and position of the baby interferes with the mother's ability to close her legs while sitting and standing, to sit up straight, to stand up straight, to bend over while sitting or standing, and to sustain adequate reach. For these reasons, workday tasks become more difficult to perform during pregnancy. However, traditional anthropometric data combined with 3-D data should help designers create workspaces that will minimize the limitations of pregnancy.

### 2.4.1 Work and Pregnancy

Naturally, the increased abdominal girth of a pregnant women reduces her working area. The enlarged abdomen may force pregnant women to stand or sit farther from the workstation, or may cause women to turn the enlarged abdomen away from the workstation, causing torsion of the trunk (Nicholls and Grieve, 1992). This increase in abdominal area may also result in postural adaptation which may lead to back discomfort. As a consequence, performance levels may change, either due to the awkwardness of the new posture adopted or to discomfort (Nicholls and Grieve, 1992).

Adjusting the workplace layout to accommodate pregnant women should make their workday tasks more manageable and allow pregnant women to continue working with increased comfort and productivity. Organizations with many female employees should consider redesigning the workplace layout to meet the needs of pregnant women because, for any organization with female workers, pregnancy is not a temporary, nine-month phenomenon, but a permanent one (Paul, Frings-Dresen, Salle, and Rozendal, 1995).

Everyday tasks may become more difficult to perform during pregnancy as well. Some tasks which become more difficult to perform include driving a car, using seatbelts, walking upstairs, reaching high shelves, getting in and out of bed, and vacuuming (Nicholls and Grieve, 1992). Equipment designed with the size and shape of pregnant women in mind could simplify these tasks.

Each woman undergoes size and shape changes during pregnancy which differ from other women's changes and which may differ from changes that occurred during their own past pregnancies. According to the data collected to date, it seems that pregnant women experience unique size and shape changes at different rates. That is, there is no "average pregnant woman." Designing a workplace layout to accommodate pregnant women in general is a difficult task, but is more conceivable with the 3-D anthropometric data. To be able to see and understand the size and shape changes associated with pregnancy allows designers to better accommodate pregnant women in the workplace.

## 2.5 Problems Encountered

### 2.5.1 Fetal Movement

Movement of the fetus during sessions presented a problem when landmarking, measuring, and scanning. For example, a certain landmark was identified and once the fetus moved or shifted positions, it became difficult to relocate the same landmark again (during the same session). Also, fetus movement during scanning caused shading in some scans. Shading will occur when there is a void in the data. Highly shaded areas usually involve the area between the legs and under the arms. The amount of shading due to fetus movement depends on the position of the fetus at the time the laser passes during the scan. For example, one subject felt the baby move as the laser passed the abdominal area. The subject commented that she could actually feel the baby's arm in this area, but was unable to move it so the scan could be repeated.

### 2.5.2 Landmark Location

Several landmarks became hard to find as the subjects progressed through pregnancy. Tenth rib is one landmark which became noticeably difficult to landmark on some subjects once the abdomen started protruding significantly. Tenth rib is the lowest point on the inferior border of the tenth (lowest palpable and last attached) rib. Sometimes, the ninth rib will be located first and used as a guideline to find the Tenth Rib. It is much easier to find the Tenth Rib landmark if the subject is carrying the baby low. Subjects that are carrying the baby high tend to present more of a problem, because palpation of the tenth rib becomes nearly impossible when the baby is in the way. Sometimes, when a landmark is difficult to find, the subjects provide useful insight.

Another series of landmarks, ASIS, PSIS, and Illiocristale, located on the pelvic girdle, became progressively harder to palpate and locate on pregnant women once the abdomen changes and muscles start to tighten. ASIS (Anterior Superior Iliac Spines) are the uppermost of two pair of prominences on the anterior rims of the ilia. The ilia are one of the three pair of bones which comprise the bony pelvis. The difficulty is due to the physical structure of the pregnant woman. The ASIS is located on the front ridge of the hip bone. During late stages of pregnancy, this landmark may be physically impossible to locate, depending on where the fetus is positioned at the time.

The humeral and femoral epicondyles also become more difficult to palpate as pregnancy progresses. The femoral epicondyles are the bony protuberances at the distal end of the right and left femur. The humeral epicondyles are the bony protuberances at the distal end of the right and left humerus. These bony points located around the knee have proven problematic with certain subjects. It is believed this is due to muscle build-up caused by carrying the extra weight of the baby and the additional weight of the mother. Excess fluid around the knee also makes the landmark more difficult to find.

Even though a few landmarks have proven difficult to locate late in the pregnancy, past experience with the subjects helps estimate where these hard-to-find landmarks might be located. Because the subjects were landmarked, measured, and scanned before any obvious body

size and shape changes occurred, those changes can be considered when locating--and sometimes estimating the location of--landmarks in later sessions.

The additional time it takes to locate landmarks on subjects late in their pregnancies is significant because it adds to the amount of time the subject spends in the CARD Lab for the data collection process. The traditional anthropometric data collection should take approximately 60 minutes, and the collection of the 3-D anthropometric data takes approximately 15 minutes. However, due to difficulty finding several landmarks, the traditional data collection time has increased to 90 minutes or longer. Subjects also need to take more frequent breaks as their pregnancies advance.

### 2.5.3 Traditional Data Collection Posture--Standing

In the standard posture for traditional data collection, the subject stands erect with the head positioned in the Frankfurt Plane, with the heels of the feet together, and the toes apart. With the exception of one, all subjects have been able to stand in this standard anthropometric posture for traditional measurements. The subject who could not assume the standard posture had experienced a back injury, and felt off-balance with her heels together. To compensate for this change in position, the subject stood erect with her head positioned in the Frankfurt plane with her heels 20 cm apart. A landmark dot was placed on the floor at both sides of her heels to provide foot placement for her next data collection session. If other subjects experience problems standing in the standard position, they will be positioned using these same set of landmark dots (with heels 20 cm apart).

Subjects have also experienced problems with instability and loss of balance which did not exist prior to pregnancy. In some cases, subjects required additional breaks during the traditional data collection process due to lightheadedness or dizziness. Standing in the standard posture for an extended period of time may cause the subject to feel faint. Subjects sometimes lock their knees while standing in this position which can cause dizziness or lightheadedness due to blood flow restriction.

### 2.5.4 Traditional Data Collection Posture--Sitting

A few subjects experienced difficulty putting their knees together for the seated hip breadth measurement. This is usually only a problem if the position of the abdomen prevents the subject from assuming the required measurement position. When this problem occurs, the subject is helped by pushing on the lateral sides of both legs very gently. Some subjects also have trouble sitting up straight during the sitting height measurement. These subjects experience lower back pain when sitting very straight, or cannot physically remain seated in an erect position for long periods of time. When this happens, the subjects are asked to sit up as straight as possible for as long as they can while the measurements are taken.

### 3.0 CONCLUSIONS

#### 3.1 Summary

As of May 1997, 35 subjects were enrolled in the study. Since then, 11 subjects have dropped out of the study due to loss of the baby, moving away from the Dayton area, medical complications, father's refusal to sign the consent form, and *permanent change in station (PCS)*. Therefore, 24 subjects remain in the study. The statistical analysis in the report includes only those subjects still remaining in the study, even though other subjects completed one or more data collection sessions. A list of subjects, including the dates when sessions were completed, appears in Appendix G. Appendix G also shows how many weeks pregnant the subjects were when their sessions were completed. Also included in Appendix G is the latest possible date for each subject to complete a given session according to pre-determined intervals (one session during the first trimester, one session during the second trimester, three sessions during the third trimester, and one post-delivery session). Researchers use this record when scheduling each subject for their next session. According to this record, four women need to complete the second session, 12 women need to complete the third session, 17 women need to complete the fourth session, 23 women need to complete the fifth session, and 23 women need to complete the post-delivery session. Due dates for the remaining subjects are listed in Table 3.1-1. The last delivery date is 15 January 1998. Data collection will continue until all the remaining sessions are completed, or until the Cyberware Whole Body Scanner is no longer available.

**TABLE 3.1-1.**  
**Delivery Dates**

SUBJECT NUMBER	DUE DATE
2	22 September 1997
3	26 August 1997
4	7 July 1997
6	7 August 1997
7	26 August 1997
8	6 September 1997
10	25 August 1997
11	6 September 1997
15	21 September 1997
16	15 September 1997
17	30 September 1997
19	8 October 1997
20	29 September 1997
21	22 September 1997
22	21 October 1997

SUBJECT NUMBER	DUE DATE
24	29 October 1997
27	16 October 1997
28	5 November 1997
29	4 November 1997
30	10 December 1997
32	11 November 1997
33	23 November 1997
34	13 December 1997
35	15 January 1998

### 3.2 "So What?"

The study's traditional anthropometric data, combined with the 3-D anthropometric data, can help ergonomists accommodate pregnant women in many different areas of design. Even though duty restrictions are based on objective medical reasons related to work environment, often the evaluation of the constraints placed on service women are subjective (e.g., in a bio-hazard environment, duty assignment could result in fetal damage). Occupations and activities critical to mission success, however, open the problem of subjective duty restriction evaluation. Several specific duties which may be affected by increasing body size or weight restriction include, but are not limited to:

- Control Panel Monitor/Operator - workspace accommodation
- Maintenance:
  - Missile Systems (silos) - accommodation
  - Vehicles - reach and accommodation
  - Aircraft - reach and accommodation
- Chemical Defense - donning gear during later stages of pregnancy
- Munitions - lifting
- Crew Chief - lifting
- Shipboard (tight quarters and ladders) - accommodation
- Military:
  - Cockpit, workspace, Protective Clothing - accommodation
  - Vehicle - accommodation and safety restraints

These data may also be used to help accommodate pregnant women in other areas of design outside the military. A 1990 General Motors study investigated anthropometry of seated pregnant women to define fetal envelopes for crash protection, but did not address the mother's overall body size for accommodation. In fact, anthropometric drawings from the University of Michigan Transportation Research Institute were used to determine the body ellipses, which were then superimposed on the appropriately-scaled female occupant. The digitized body shapes were fit by a spline curve approximation in a computer-aided design

program (Culver and Viano, 1990). By using the 3-D whole body scan data, designers can determine a normal abdominal ellipse for different sizes of women at various stages of pregnancy much more accurately. The whole body scans are much more useful than drawings--they are actual 3-D representations of the human body. This information can help enhance crash protection for pregnant women and help improve the design of restraints for pregnant women. Anthropometrically correct female manikins, at various stages of pregnancy, could also be developed from these data.

The design of maternity clothing could also benefit from the Pregnant Women's Study data. Many women feel that existing maternity clothing restricts their ability to reach. Reach concerns are relevant to all occupations requiring uniform, protective clothing, or a standard dress code whether it be military or non-military (Nicholls and Grieve, 1992). One study in Japan involved taking measurements on 520 pregnant women to obtain basic data for designing pregnant women's garments. The Japanese predicted that the size of a pregnant woman's garment cannot be decided according to a month of pregnancy. Pregnant women's garments must be designed with consideration of the variety of sizes and shapes of the body, changing with the progress of pregnant months (Yamana, et al., 1984). The Pregnant Women's Study 3-D data will provide the shape changes associated with nine months of pregnancy, and therefore, provide accurate data for the design of maternity clothing.

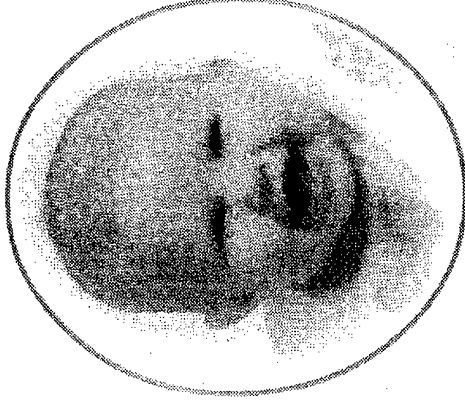
### 3.3 Recommended Changes or Future Work

At this time, the only recommendation for change for future work involves the recruitment of subjects. Subject participation was lower than expected, and with the study's limited time frame, it was impossible to reach the desired goal of 50 subjects to start the study. It is suggested that subjects should be recruited from several hospitals instead of one. Local doctors' offices may be helpful as well. If all of the subjects must be in the military, a larger base hospital should be used for the subject pool. Because of the low subject participation rate, military subjects had to be augmented with non-military subjects in order to reach a sample size large enough for statistical significance.

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# Pregnant Women needed as volunteers:

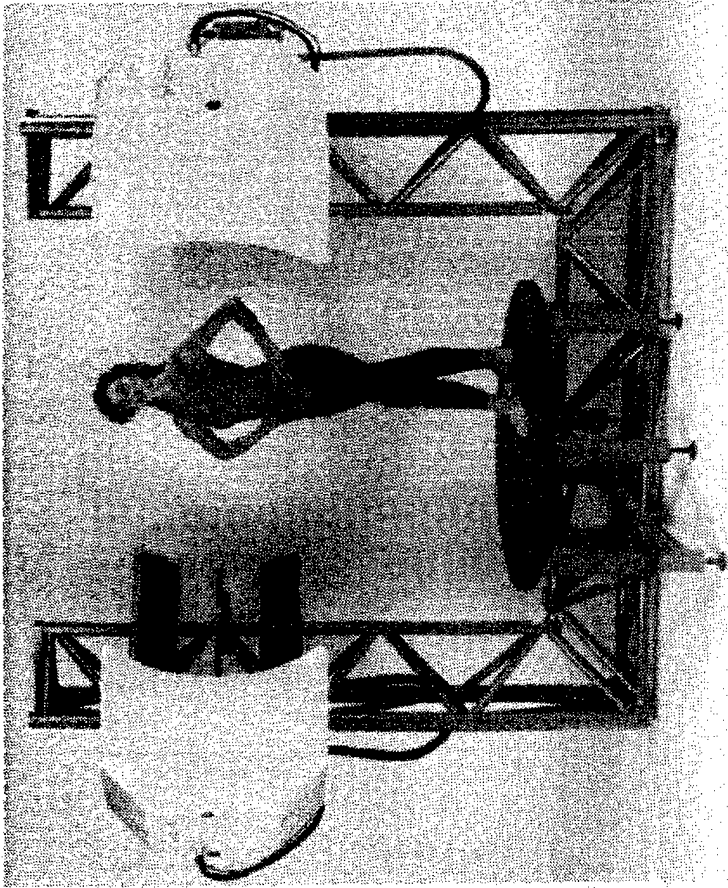


Pregnant women are needed as volunteers for a study at Wright-Patterson Air Force Base that addresses body size and shape changes associated with pregnancy.

---

**Qualified subjects will be paid \$8.00 an hour. If you are interested please contact:**

**TERESA CRASE**  
**255-0865**



### *Three Dimensional Anthropometric Data*

Researchers will use the Cyberware WB4 Whole Body Scanner (shown above) to collect your three-dimensional data. A typical scan takes less than 20 seconds. The whole body scanner uses three-dimensional digitizers to capture surface shape and color information on the human body to create a 3-D image. To date, there is no other 3-D anthropometric data on pregnant women! This type of data provides the *shape* information designers need to help accommodate pregnant women.

## Qualifications

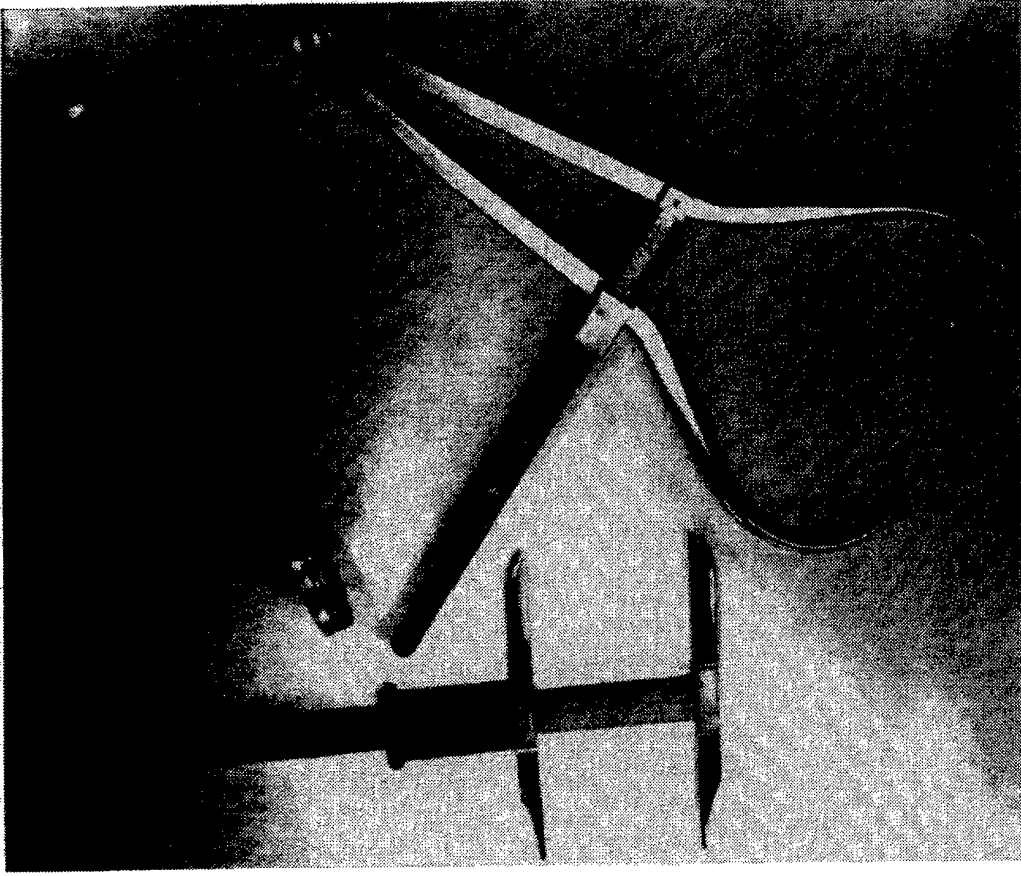
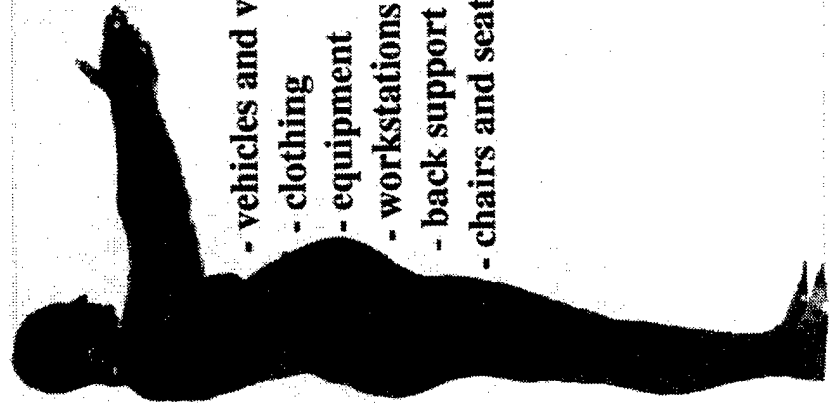
We need women who are are:

- 18-40 years of age
- active duty military or civilian
- any race/ethnic background
- in their first trimester (before any noticeable weight and/or body changes occur)



The data collected will be applied to help accommodate pregnant women in many different areas of design including:

- vehicles and vehicle constraints
- clothing
- equipment
- workstations and workplaces in general
- back support systems
- chairs and seating



## Traditional Anthropometric Data

Anthropometry is the measurement of the human body. Researchers will use traditional measuring tools (such as the calipers, tape measurers, and anthropometers shown above) to measure a number of dimensions on your body. This type of data provides the size information designers need to help accommodate pregnant women.

**APPENDIX B**

***SKYWRITER* ARTICLES**

Wright-Patterson Air Force Base

# Skywriter

Vol. 38, No. 10

Wright-Patterson AFB, Ohio

Friday, March 14, 1997

## NEWS BRIEFS

### Pregnant women studied

The Accommodation and Occupational Safety for Military Personnel research study needs pregnant women to volunteer. The goal is to address the body size and shape changes associated with pregnancy. Volunteers should be between 18 and 40 years old, within Air Force duty military or civilian, of any race or ethnic background, and in their first trimester of pregnancy before any noticeable weight or body changes occur. The data will be applied to help accommodate pregnant women in different areas of design including vehicles and clothing. For more information, call Teresa Craze at 255-0865.

**APPENDIX C**  
**PAYROLL RECORD FORM**



**APPENDIX D**

**LANDMARKS, DIMENSIONS,  
AND GLOSSARY OF TERMS**

**APPENDIX D**  
**THE ANTHROPOMETRY**

**D.1      MARKED LANDMARKS (In Marking Order)**

**Standing:**

1.      Axilla (8)
2.      Bustpoint (2)
3.      Substernale
4.      Tenth Rib (2)
5.      Waist Level, Preferred (8)
6.      Waist Level, Omphalion (8)
7.      PSIS (2)
8.      ASIS (2)
9.      Illiocristale (2)
10.     Buttock Point (3)
11.     Suprapatella (2)
12.     Malleolus, Lateral (2)
13.     Malleolus, Medial (2)
14.     Metatarsal I (2)
15.     Metatarsal V (2)

**Sitting:**

16.     Tragion (2)
17.     Infraorbitale (2)
18.     Suprasternale
19.     Cervicale
20.     Spine<sup>1</sup> (4)
21.     Acromion (2)
22.     Humeral Epicondyles (4)
23.     Radial Stylium (2)
24.     Ulnar Styloids (2)
25.     Metacarpale II (2)
26.     Metacarpale V (2)
27.     Femoral Epicondyles (4)

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<sup>1</sup> *Spine* landmarks will be established on the center of the spine at 10 cm intervals from cervicale.

D.2

**LANDMARK DESCRIPTIONS** (In Alphabetical Order)

1. **Acromion:** The most lateral point on the acromial process of the scapula.
2. **ASIS (Anterior Superior Iliac Spines):** The uppermost of two pair of prominences (the other is the anterior inferior iliac spine) on the anterior rims of the ilia. (The ilia are one of the three pair of bones which comprise the bony pelvis).
3. **Axilla:** The armpit.
4. **Bustpoint:** The most anterior protrusion of the right bra pocket.
5. **Buttock Point:** The maximum posterior protrusion of the right buttock.
6. **Cervicale:** The superior tip of the spine of the 7<sup>th</sup> cervical vertebra, generally characterized by a protrusion of the spinal column at the base of the neck.
7. **Femoral Epicondyles:** The bony protuberance at the distal end of the right and left femur.
8. **Humeral Epicondyles:** The bony protuberance at the distal end of the right and left humerus.
9. **Iliocristale:** Title for the superior rim of the ilium in the right and left mid-lateral lines.
10. **Infraorbitale:** The lowest point on the inferior margin of the orbit or bony eye socket.
11. **Malleolus, Lateral:** The lateral bony protrusion of the ankle; the most lateral point on the lateral bony protrusion of each ankle.
12. **Malleolus, Medial:** The medial bony protrusion of the ankle; the most medial point on the medial bony protrusion of each ankle.
13. **Metacarpale II:** The most protruding point on the lateral edge of the bony prominence (knuckle) formed by the joint between the second metacarpal and phalanx of the second (pointer) finger.
14. **Metacarpale V:** The most protruding point on the lateral edge of the bony prominence (knuckle) formed by the joint between the fifth metacarpal and phalanx of the fifth (pinkie) finger.

15. **Metatarsal I:** The joint formed between the bones of the foot and the first bone of the big toe; the "ball-of-the-foot."
16. **Metatarsal V:** The joint formed between the bones of the foot and the first bone of the little toe.
17. **PSIS (Posterior Superior Iliac Spines):** The point on the mid-spine made at the level of the posterior superior iliac spines. A dimple often indicates the site of the iliac spine.
18. **Radial Styliion:** The tip of the styloid process at the distal end of the radius, on the thumb side of the wrist.
19. **Spine:** Three points located at intervals equally spaced from the cervicale landmark. The intervals will range from 15-20 cm, depending on the length of the individual's torso.
20. **Substernale:** The middle of the lower end of the breastbone.
21. **Suprapatella:** The top of the kneecap; the superior point on the patella while it is in the relaxed (loose) position.
22. **Suprasternale:** The lowest point of the (jugular) notch at the upper end of the breastbone (sternum).
23. **Tenth Rib:** The lowest point on the inferior border of the tenth (lowest palpable) rib.
24. **Tragion:** A point at the notch just above the tragus of each ear. This point corresponds (approximately) to the upper edge of the ear hole.
25. **Ulnar Styloids:** The most distal point of the right and left ulna.
26. **Waist Level, Preferred:** The level of the waist established by the subject placing an elastic tape at his or her preferred waist level.
27. **Waist Level, Omph:** The waist at the level of navel (umbilicus).

D.3

**DIMENSION LIST** (In Measurement Order)

1. Thumbtip Reach, Right
2. Weight
3. Stature
4. Cervicale Height
5. Suprasternale Height
6. Substernale Height
7. Chest Height
8. Chest Height Below Bust
9. Tenth Rib Height
10. Waist Height, Preferred
11. Waist Height, Omph
12. Patella Top Height<sup>2</sup>
13. Chest Breadth
14. Chest Breadth Below Bust
15. Waist Breadth, Preferred
16. Waist Breadth, Omph
17. Hip Breadth
18. Chest Depth
19. Chest Depth Below Bust
20. Waist Depth, Preferred
21. Waist, Depth, Omph
22. Chest Circumference
23. Chest Circumference Below Bust
24. Waist Circumference, Preferred
25. Waist Circumference, Omph
26. Hip Circumference
27. Thigh Circumference
28. Calf Circumference
29. Ankle Circumference
30. Foot Breadth
31. Sitting Height
32. Cervicale Height, Sitting
33. Knee Height, Sitting
34. Buttock-Knee Length
35. Abdominal Extension Depth, Sitting
36. Hip Breadth, Sitting
37. Hand Breadth

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<sup>2</sup> *Knee Height measured at suprapatella.*

**DIMENSION DESCRIPTIONS** (In Alphabetical Order)

1. **Abdominal Extension Depth, Sitting:** The subject sits erect on a flat surface looking straight ahead. The upper arms are hanging relaxed at the sides with the forearms and hands extended forward horizontally with the palms facing each other. The abdominal muscles are relaxed. The horizontal distance is measured between the back and the most protrusive point of the abdomen.
2. **Ankle Circumference:** The subject stands with the legs slightly apart and the weight distributed equally on both feet. The minimum circumference of the right ankle above the ankle bone is measured.
3. **Buttock-Knee Length:** The subject sits erect on a flat surface looking straight ahead. The thighs are parallel, and the feet are in line with the thighs on a surface adjusted so that the knees are bent 90 degrees. The horizontal distance is measured between the most protrusive point of the right buttock and the most forward point of the knee.
4. **Cervicale Height:** The subject stands erect looking straight ahead with the line of vision parallel to the floor. The arms hang relaxed at the sides, and the heels are together with the weight distributed equally on both feet. The vertical distance is measured between the standing surface and the top of the spine of the 7<sup>th</sup> cervical vertebra (cervicale) which is the lowest vertebra of the neck.
5. **Cervicale Height, Sitting:** The vertical distance between a sitting surface and the cervicale landmark on the spine at the base of the neck is measured with an anthropometer. The subject sits erect looking straight ahead. The shoulders and upper arms are relaxed and the forearms and hands are extended forward horizontally with the palms facing each other. The thighs are parallel and the knees are flexed 90 degrees.
6. **Calf Circumference:** The subject stands with the weight equally distributed on both feet. The maximum circumference of the right lower leg is measured perpendicular to its long axis.
7. **Chest Breadth:** The subject stands erect looking straight ahead. The arms hang relaxed at the sides. The horizontal breadth of the chest is measured at the level of the nipples on men or the most protrusive point of a bra on women or of the right nipple on men.
8. **Chest Breadth Below Bust:** The subject stands erect looking straight ahead. The arms hang relaxed at the sides. The horizontal breadth of the chest is measured at the lowest point of the bottom edge of a bra on women or of the right nipple on men.

9. **Chest Circumference:** The subject stands erect looking straight ahead with the arms hanging relaxed at the sides. The horizontal circumference of the chest is measured at the level of the most protrusive point of the right bra pocket on women or of the right nipple on men.
10. **Chest Circumference Below Bust:** The subject stands erect looking straight ahead with the arms hanging relaxed at the sides. The horizontal circumference of the chest is measured at the lowest point of the bottom edge of a bra on women or at the lowest point of the breasts on men.
11. **Chest Depth:** The subject stands erect looking straight ahead with the arms hanging relaxed at the sides. The horizontal depth of the chest is measured from the front to back at the level of the most protrusive point of the right bra pocket on women or of the right nipple on men.
12. **Chest Depth Below Bust:** The subject stands erect looking straight ahead with the arms hanging relaxed at the sides. The horizontal depth of the chest is measured at the lowest point of the bottom edge of a bra on women or of the right nipple on men.
13. **Chest Height:** The subject stands erect looking straight ahead. The arms hang relaxed at the sides, and the heels are together with the weight distributed equally on both feet. The vertical distance is measured between the standing surface and the most protrusive point of the right bra pocket on women and the right nipple on men.
14. **Chest Height Below Bust:** The subject stands erect looking straight ahead. The arms hang relaxed at the sides, and the heels are together with the weight distributed equally on both feet. The vertical distance is measured between the standing surface and the lowest point of the bottom edge of a bra on women or of the right nipple on men.
15. **Foot Breadth:** The subject stands with the weight distributed equally on both feet. The maximum horizontal distance across the right foot perpendicular to its long axis is measured between the inside and outside of the foot.
16. **Hand Breadth:** The right hand is held, palm down, flat on a table. The fingers are straight and touching and the thumb is held slightly away from the side of the hand. The straight-line distance across the hand is measured between the sides of the knuckles at the first and little fingers at the points of their greatest protrusion (metacarpale) at the sides of the hand.
17. **Hip Breadth:** The subject stands erect looking straight ahead. The arms are hanging relaxed at the sides, and the heels are together with the weight

distributed equally on both feet. The maximum horizontal distance is measured between the widest points of the hips.

18. **Hip Breadth, Sitting:** The subject sits erect on a flat surface. The maximum horizontal breadth across the hips or thighs is measured. In the USN '64, USAF '65, and USAF '67 surveys, the subjects sat with their thighs parallel. In the USA '66, USAF '68, and USA '77 surveys, the subjects sat with their knees together.
19. **Hip Circumference:** The subject stands erect looking straight ahead. The arms hang relaxed at the sides, and the heels are together with the weight distributed equally on both feet. The horizontal circumference of the hips is measured at the level of the maximum protrusion of the buttocks.
20. **Knee Height, Sitting:** The subject sits erect on a flat surface. The thighs are parallel, and the feet are in line with the thigh on a surface adjusted so that the knees are bent 90 degrees. The vertical distance is measured between the foot rest and the top of the right knee (USN 64, USAF 65, USA 66, and USAF 67). In the USA '70 and USA '77 surveys, this dimension was measured to a point 5 cm (about 2 in) behind the top of the kneecap on the top of the thigh of the seated subject.
21. **Overhead Fingertip Reach:** The vertical distance between a standing surface and the tip of the right middle finger when the arm is extended overhead is measured on a wall scale. The subject stands facing a wall-mounted scale with both arms extended overhead parallel to each other. The toes are 20 cm from the wall and the feet are about 10 cm apart. The palms of the hands rest on the scale. A block is placed against the tip of the finger to establish the measurement.
22. **Patella Top Height:** The subject stands erect looking straight ahead with the heels together and the weight distributed equally on both feet. The vertical distance is measured between the standing surface and the topmost point of the right kneecap (patella).
23. **Sitting Height:** The subject sits erect on a flat surface looking straight ahead with the line of vision parallel to the floor. The vertical distance is measured between the sitting surface and the top of the head.
24. **Stature:** The subject stands erect looking straight ahead with the line of vision parallel to the floor. The arms are relaxed at the sides, and the heels are together with the weight distributed equally on both feet. The vertical distance is measured between the standing surface and the top of the head.

25. **Substernale Height:** The subject stands erect looking straight ahead. The arms hang relaxed at the sides, and the heels are together with the weight distributed equally on both feet. The vertical distance is measured between the standing surface and the lowest point (substernale) of the sternum (the sternum is the breast bone).
26. **Suprasternale Height:** The subject stands erect looking straight ahead with the line of vision parallel to the floor. The arms hang relaxed at the sides, and the heels are together with the weight distributed equally on both feet. The vertical distance is measured between the standing surface and the point of lowest depression (suprasternale) in the top of the sternum (the breast bone).
27. **Tenth Rib Height:** The vertical distance between a standing surface and the tenth rib landmark at the bottom of the right side of the rib cage is measured with an anthropometer. The subject stands erect looking straight ahead. The heels are together with the weight distributed equally on both feet. The shoulders and upper extremities are relaxed.
28. **Thigh Circumference:** The subject sits back on a flat surface with the thighs just touching each other and completely supported by the sitting surface. The feet are unsupported. The vertical circumference of the right thigh is measured at the lowest point of the thigh/buttock juncture (as close to the crotch as possible).
29. **Thumbtip Reach:** The subject stands erect with the heels together. The heels, the buttocks, and the shoulder blades touch a wall. The right arm is straight and held forward horizontally. The tip of the index finger touches the pad of the thumb which is held straight in line with the long axis of the forearm and hand. The horizontal distance is measured between the back (the wall) and the tip of the thumb.
30. **Waist Breadth, Omphalion:** The subject stands erect looking straight ahead with the arms hanging relaxed at the sides. The horizontal breadth of the torso is measured at the level of the center of the navel (omphalion).
31. **Waist Breadth, Preferred:** The subject stands erect looking straight ahead with the arms hanging relaxed at the sides. The horizontal breadth of the torso is measured at the level established by the subject placing an elastic tape at his or her preferred waist level.
32. **Waist Circumference, Omphalion:** The subject stands erect looking straight ahead breathing quietly. The upper arms hang relaxed at the sides, and the abdominal muscles are relaxed. The maximum horizontal

circumference of the waist is measured at the level of the center of the navel (omphalion).

33. **Waist Circumference, Preferred:** The subject stands erect looking straight ahead breathing quietly. The upper arms hang relaxed at the sides, and the abdominal muscles are relaxed. The maximum horizontal circumference of the waist is measured at the level of the waist established by the subject placing an elastic tape at his or her preferred waist level.
34. **Waist Depth, Omphalion:** The subject stands erect looking straight ahead with the arms hanging relaxed at the sides. The abdominal muscles are relaxed. The horizontal distance is measured between the subject's back and the center of the navel (omphalion).
35. **Waist Depth, Preferred:** The subject stands erect looking straight ahead with the arms hanging relaxed at the sides. The abdominal muscles are relaxed. The horizontal distance is measured between the subject's back and the level of the waist established by the subject placing an elastic tape at his or her preferred waist level.
36. **Waist Height, Omphalion:** The subject stands erect looking straight ahead. The arms are hanging relaxed at the sides, and the heels are together with the weight distributed equally on both feet. The abdominal muscles are relaxed. The maximum vertical distance is measured between the standing surface and the center of the navel (omphalion).
37. **Waist Height, Preferred:** The subject stands erect looking straight ahead. The arms are hanging relaxed at the sides, and the heels are together with the weight distributed equally on both feet. The abdominal muscles are relaxed. The maximum vertical distance is measured between the standing surface and the level of the waist established by the subject placing an elastic tape at his or her preferred waist level.
38. **Weight:** The nude<sup>3</sup> subject stands on scales with the feet parallel and the weight distributed equally on both feet.

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<sup>3</sup> "Nude" subjects are not literally nude; they are clad in lightweight garments similar to biking shorts and a sport bra.

## D.5 GLOSSARY OF RELATED TERMS

### D.5.1 Orientation Terminology

1. **Anterior:** Pertaining to the *front* of the body, as opposed to posterior.
2. **Posterior:** Pertaining to the *back* of the body, as opposed to anterior.
3. **Lateral:** Lying near or toward the *sides* of the body; located to the right or left of the vertical fore-and-aft midline (the midsagittal plane) of a bilaterally symmetrical body. The opposite of lateral is medial.
4. **Medial:** Lying near or toward the *midline* of the body; toward the *midsagittal plane*; the opposite of lateral.
5. **Superior:** Above, in relation to another structure; higher.
6. **Inferior:** Below, in relation to another structure; lower.
7. **Proximal:** The end of a body segment *nearest* to the head; nearest a point of origin; *nearest the head or torso*. The opposite of proximal is distal.
8. **Distal:** The end of a body segment *farthest* from the head; away from the point of origin; *away from the head or torso*. The opposite of distal is proximal.
9. **Frankfort Plane:** The standard horizontal plane or orientation of the head. The plane is established by a line passing through the right tragion (approximately, above the hole of the ear) and the right orbit (eye socket).

### D.5.2 Common Prefixes

1. **Sub-:** A prefix designating below, or under.
2. **Supra-:** A prefix designating above, or on.
3. **Infra-:** Below, beneath, or inferior to.

### D.5.3 General Information

1. **Acromiale:** Acromion.
2. **Ilia:** One of the three pairs of bones which comprise the bony pelvis; plural of Ilium.
3. **Iliac:** Of, referring to, or located near the Ilium.

4. **Ilium:** The upper of the three pairs of bones composing either lateral half (right or left) of the pelvis (the other pairs of bones are the ischium and pubis).
5. **Ischium:** The lowest of the three major bones which comprise each half of the bony pelvis.
6. **Meatus:** A body canal or passage.
7. **Midsagittal Plane:** The vertical plane which divides the body into right and left halves.
8. **Orbit:** The bony eye socket.
9. **Palpate:** Examination by touch. Anatomical landmarks are located either by palpation or by visual inspection.
10. **Process:** A part extending from an organ or organism: an appendage. [Example 1: The acromial process extends from the top of the scapula. Example 2: The styloid process is a body protuberance resembling a stylus at the distal ends of the radius and ulna].
11. **Protuberance:** That which protrudes; a bulge or knob; a protrusion.
12. **Protrusion:** That which protrudes; a bulge or knob; a protuberance.
13. **Pubis:** The front or forward section of the bony pelvis; the last of the three bones which comprise each half of the bony pelvis.
14. **Scapula:** The shoulder blade.
15. **Sternum:** The breast bone.
16. **Tragus:** The small cartilaginous flap in front of the external auditory meatus of the skull (the ear hole).
17. **Umbilicus:** The navel. Omphalion is the corresponding landmark name.
18. **USA:** Abbreviation for the United States Army.
19. **USAF:** Abbreviation for the United States Air Force.
20. **USN:** Abbreviation for the United States Navy.

#### D.5.4

#### Description of Dimension Types

1. **Height** is a straight line, point-to-point vertical measurement.
2. **Breadth** is a straight line, point-to-point horizontal measurement running across the body or a segment.
3. **Depth** is a straight line, point-to-point horizontal measurement running from ventral (front) to dorsal (back).
4. **Circumference** is a closed measurement that follows a body contour; this measurement may not be circular.
5. **Reach** is a point-to-point measurement following the long axis of the arm or leg.

**APPENDIX E**  
**QUESTIONNAIRE**

SUBJECT NO.:

(To be completed by SYTRONICS only).

PREGNANT WOMEN'S STUDY

QUESTIONNAIRE

**NOTICE:** The Privacy Act, 5 U.S.C. 552a, requires that federal agencies inform individuals, at the time information is solicited from them, whether the disclosure is mandatory or voluntary, by what authority such information is solicited, and what uses will be made of the information. You are hereby advised that authority for soliciting the following voluntary information is Grant No.: DAMD17-96-1-6311 and that all information provided will be used strictly for research purposes only. All personal information will be kept strictly CONFIDENTIAL.

A PERSONAL DATA		
NAME:	DATE:	
ADDRESS:	WORK PHONE:	HOME PHONE:
<hr/>	<hr/>	<hr/>

**RACE/ETHNIC BACKGROUND:** According to the RACE/ETHNIC BACKGROUND descriptions explained below, please identify the mother's race, father's race, and baby's race by placing the corresponding number in the appropriate block.

- #1. **WHITE** (Not of Hispanic Origin): All persons having origins in any of the original peoples of Europe, North Africa, or the Middle East.
- #2. **BLACK** (Not of Hispanic Origin): All persons having origins in any of the Black racial groups of Africa.
- #3. **HISPANIC:** All persons of Mexican, Puerto Rican, Central or South American or other Spanish culture or origin, regardless of race (includes those with Hispanic surnames).
- #4. **AMERICAN INDIAN OR ALASKA NATIVE:** All persons having origins in any of the original peoples of North America, and who maintain cultural identification through tribal affiliation or community recognition.
- #5. **ASIA OR PACIFIC ISLANDER:** All persons having origins in any of the original peoples of the Far East, Southeast Asia, the Indian Subcontinent, or the Pacific Islands. This area includes, for example, China, Japan, Korea, the Philippine Islands, and Samoa.
- #6. **OTHER:** Please specify.

BABY'S MOTHER	BABY'S FATHER	BABY'S
Race/Ethnic Background No.: <input type="checkbox"/>	Race/Ethnic Background No.: <input type="checkbox"/>	Race/Ethnic Background No.: <input type="checkbox"/>
NOTE: If #6, please identify here:	NOTE: If #6, please identify here:	NOTE: If #6, please identify here:
OTHER: <hr/>	OTHER: <hr/>	OTHER: <hr/>

ABOUT YOUR PREGNANCY(S)	
HOW FAR ALONG ARE YOU? <hr/> Months	DUE DATE: <hr/>
NUMBER OF PREVIOUS LIVE BIRTHS: <hr/>	NUMBER OF PREGNANCIES (Including this one): <hr/>

**Ⓑ OCCUPATION**

AFSC:	JOB TITLE:
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**PLEASE CIRCLE ONE**

1. Do you smoke? If YES, how many cigarettes do you smoke per day? _____	YES	NO	
2. Has this changed since you became pregnant? If YES, how? _____	YES	NO	
3. Is your job a desk or non-desk job?	DESK	NON-DESK	
4. How many hours do you work in one day? _____			
5. How many hours do you work in one week? _____			
6. Do you stand, sit, or both stand and sit on the job?	STAND	SIT	BOTH

**IF YOU STAND ON THE JOB, GO TO QUESTION 7.**  
**IF YOU SIT ON THE JOB, GO TO QUESTION 8.**  
**IF YOU STAND AND SIT ON THE JOB, ANSWER BOTH QUESTION 7 AND 8.**

7. **If your job is done primarily standing, then:**

(a) Please describe your work area. Specifically address where you stand, whether your table/desk/workstation is adjustable, etc. Please be as descriptive as possible.

*Example: I work in an office which handles money, cashier tills, accounting, etc. The room is approximately 25 feet long and 8 feet wide. There is a large vault at one end of the room which has a large, heavy door. I stand at a counter which is between 3 feet and 4 feet tall. The counter is a fixed height and does not adjust. I periodically move to other parts of the room to answer the telephone, go into the vault, etc.*

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(b) How many hours per day do you actually stand? \_\_\_\_\_

**OR,** what percentage (%) of the time do you stand while you work? \_\_\_\_\_

(c) How long do you work in a standing position at one time (5 minutes, 30 minutes, 1 hour, etc.)? \_\_\_\_\_

(d) Do you operate machinery while you are standing? \_\_\_\_\_

If YES, please explain in detail what type of machine you work with or operate.

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*(Continued on next page).*

7. (Cont'd)

- (e) While standing, do you lift any type of object(s)? \_\_\_\_\_
- If YES, approximately how much do the objects weigh? \_\_\_\_\_
- What size are the objects? \_\_\_\_\_
- How often do you lift the object(s) (5 times/hour, etc.)? \_\_\_\_\_

8. If your job is done primarily sitting, then:

- (a) Please describe your work area. Specifically address where you sit, whether your seat or workstation is adjustable, etc. Please be as informative as possible.

*Example: I work in a huge room which has a number of desks lined up in rows. There are partitions between each desk which act as walls. The cubes are very small, approximately 8 feet by 6 feet. The chair in which I sit adjusts in height as well as the angle at which I sit.*

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- (b) How many hours per day do you actually sit? \_\_\_\_\_
- OR, what percentage (%) of the time do you sit while you work? \_\_\_\_\_
- (c) How long do you work in a sitting position at one time (5 minutes, 30 minutes, 1 hour, etc.)? \_\_\_\_\_
- (d) Do you operate machinery while you are sitting? \_\_\_\_\_
- If YES, please explain in detail what type of machine or device you work with or operate.

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- (e) While sitting, do you lift any type of object(s)? \_\_\_\_\_
- If YES, approximately how much do the objects weigh? \_\_\_\_\_
- What size are the objects? \_\_\_\_\_
- How often do you lift the object(s) (5 times/hour, etc.)? \_\_\_\_\_

**PLEASE COMPLETE THE REST OF THE QUESTIONNAIRE,  
WHICH INCLUDES QUESTIONS 9-16.**

PLEASE CIRCLE ONE

9. During the work day, do you ever have difficulty reaching for an object or objects with one arm? YES NO

If YES, how far do you think you reach?

Do the object(s) you reach for have good handles, grips, etc.?

Which direction(s) do you typically reach (up, to the left, etc.)?

10. During the work day, do you ever have difficulty reaching for an object or objects with both arms? YES NO

If YES, how far do you think you reach?

Do the object(s) you reach for have good handles, grips, etc.?

Which direction(s) do you typically reach (up, to the left, etc.)?

11. Do you perform any typing tasks? YES NO

If YES, is there a wrist pad in front of the keyboard?

How many hours of the day do you spend typing?

12. Do you take breaks? YES NO

If YES, how often do you take breaks?

How long does each break last?

13. Do you break for a lunch? YES NO

If so, how long?

14. Considering your work environment, do you foresee pregnancy hindering or limiting your job performance in any way? YES NO

Please explain your answer.

Blank lines for explaining the answer to question 14.



**APPENDIX F**

**RATIO OF DISTANCES BETWEEN  
SESSIONS FOR SUBJECT 4**

**APPENDIX F**

**RATIO OF DISTANCES BETWEEN SESSIONS FOR SUBJECT 4**

SESSIONS	DISTANCE RATIO OF 1 TO 6	DISTANCE RATIO OF 1 TO 7	DISTANCE RATIO OF 1 TO 8	DISTANCE RATIO OF 1 TO 11	DISTANCE RATIO OF 1 TO 12	DISTANCE RATIO OF 1 TO 13
1 to 2	0.95437	1.39763	1.14307	0.93780	0.97288	0.94103
1 to 4	1.19789	1.25138	1.72810	0.85369	0.85438	0.84473
1 to 5	0.78150	0.91814	0.88064	0.88821	0.91164	0.88732
1 to 6	1.35340	1.12375	0.90975	0.88123	.090989	0.87787
2 to 4	1.25516	0.89536	1.51180	0.91031	0.87820	0.89767
2 to 5	0.81886	0.65693	0.77041	0.94713	0.93706	0.94292
2 to 6	1.41811	0.80404	0.79588	0.93968	0.93525	0.93288
4 to 5	0.65240	0.73370	0.50960	1.04044	1.06703	1.05042
4 to 6	1.12982	0.89800	0.52645	1.03226	1.06497	1.03923
5 to 6	1.73180	1.22393	1.03306	0.99214	0.99807	0.98935

SESSIONS	DISTANCE RATIO OF 1 TO 14	DISTANCE RATIO OF 1 TO 15	DISTANCE RATIO OF 1 TO 16	DISTANCE RATIO OF 1 TO 17	DISTANCE RATIO OF 1 TO 18	DISTANCE RATIO OF 1 TO 19
1 to 2	0.90283	0.89592	0.88714	0.86762	0.89030	0.91018
1 to 4	0.76150	0.82013	0.66536	0.67983	0.74865	0.83360
1 to 5	0.81948	0.88068	0.67425	0.68398	0.79209	0.83150
1 to 6	0.88937	0.86370	0.86182	0.82651	0.85982	0.88470
2 to 4	0.84346	0.91540	0.75001	0.78356	0.84090	0.91587
2 to 5	0.90768	0.98299	0.76002	0.78834	0.88969	0.91355
2 to 6	0.98509	0.96404	0.97146	0.95262	0.96577	0.97201
4 to 5	1.07613	1.07383	1.01335	1.00610	1.05803	0.99747
4 to 6	1.16792	1.05313	1.29527	1.21577	1.14850	1.06130
5 to 6	1.08529	0.98072	1.27821	1.20839	1.08551	1.06399

SESSIONS	DISTANCE RATIO OF 1 TO 20	DISTANCE RATIO OF 1 TO 21	DISTANCE RATIO OF 1 TO 22	DISTANCE RATIO OF 1 TO 23	DISTANCE RATIO OF 4 TO 6	DISTANCE RATIO OF 4 TO 7
1 to 2	0.85582	0.84883	0.83580	0.93335	1.19029	1.15352
1 to 4	0.71348	0.71068	0.82654	0.94767	1.55282	1.15324
1 to 5	0.82085	0.82110	0.88155	0.94283	0.86098	0.75822
1 to 6	0.87890	0.84140	0.84486	0.95979	1.35113	1.03570
2 to 4	0.83368	0.83725	0.98892	1.01535	1.30457	0.99975
2 to 5	0.95914	0.96734	1.05475	1.01016	0.72334	0.65731
2 to 6	1.02697	0.99125	1.01084	1.02833	1.13513	0.89786
4 to 5	1.15048	1.15537	1.06656	0.99489	0.55446	0.65747
4 to 6	1.23185	1.18394	1.02216	1.01279	0.87011	0.89808
5 to 6	1.07072	1.02473	.095837	1.01799	1.56930	1.36596

SESSIONS	DISTANCE RATIO OF 4 TO 8	DISTANCE RATIO OF 4 TO 18	DISTANCE RATIO OF 4 TO 19	DISTANCE RATIO OF 4 TO 22	DISTANCE RATIO OF 4 TO 23	DISTANCE RATIO OF 5 TO 6
1 to 2	0.88747	0.95889	0.91589	0.90113	0.91018	1.26296
1 to 4	1.34252	0.81020	0.85752	0.89245	0.94341	1.58597
1 to 5	0.73994	0.80363	0.80042	0.90653	0.89204	0.98321
1 to 6	0.80902	0.88634	0.88901	0.86888	0.95295	1.38533
2 to 4	1.51275	0.84494	0.93627	0.99036	1.03651	1.25576
2 to 5	0.83377	0.83809	0.87393	1.00600	0.98007	0.77850
2 to 6	0.91160	0.92434	0.97065	0.96422	1.04699	1.09689
4 to 5	0.55116	0.99189	0.93341	1.01579	0.94555	0.61994
4 to 6	0.60261	1.09397	1.03672	0.97360	1.01012	0.87349
5 to 6	1.09335	1.10292	1.11068	0.95847	1.06828	1.40898

SESSIONS	DISTANCE RATIO OF 5 TO 7	DISTANCE RATIO OF 5 TO 8	DISTANCE RATIO OF 5 TO 18	DISTANCE RATIO OF 5 TO 19	DISTANCE RATIO OF 5 TO 22	DISTANCE RATIO OF 5 TO 23
1 to 2	1.39334	1.03660	0.97967	0.94985	0.92238	0.94806
1 to 4	1.43295	1.15771	0.84606	0.91665	0.91647	0.99800
1 to 5	0.80633	0.78613	0.85210	0.83246	0.96427	0.91849
1 to 6	1.08427	0.85572	0.93515	0.93212	0.91101	0.97522
2 to 4	1.02843	1.11684	0.86362	0.96505	0.99359	1.05268
2 to 5	0.57870	0.75838	0.86978	0.87642	1.04542	0.96881
2 to 6	0.77818	0.82551	0.95455	0.98134	0.98768	1.02864
4 to 5	0.56271	0.67904	1.00713	0.90815	1.05216	0.92032
4 to 6	0.75667	0.73915	1.10529	1.01688	0.99405	0.97717
5 to 6	1.34469	1.08852	1.09746	1.11972	0.94477	1.06176

SESSIONS	DISTANCE RATIO OF 6 TO 7	DISTANCE RATIO OF 6 TO 8	DISTANCE RATIO OF 6 TO 13	DISTANCE RATIO OF 6 TO 14	DISTANCE RATIO OF 6 TO 15	DISTANCE RATIO OF 6 TO 16
1 to 2	1.29319	1.00430	1.10312	1.04617	1.03932	1.01160
1 to 4	1.61401	1.45675	1.03015	0.84197	1.04012	0.77406
1 to 5	0.86280	0.78175	0.96193	0.89547	0.93174	0.73057
1 to 6	1.26317	0.98644	0.99454	0.94962	1.00936	0.95645
2 to 4	1.24809	1.45051	0.93385	0.80481	1.00077	0.76518
2 to 5	0.66719	0.77840	0.87201	0.85595	0.89649	0.72219
2 to 6	0.97679	0.98222	0.90157	0.90771	0.97117	0.94548
4 to 5	0.53457	0.53664	0.93377	1.06354	0.89580	0.94382
4 to 6	0.78263	0.67715	0.96543	1.12785	0.97042	1.23563
5 to 6	1.46404	1.26184	1.03391	1.06047	1.08330	1.30918

SESSIONS	DISTANCE RATIO OF 6 TO 17	DISTANCE RATIO OF 6 TO 18	DISTANCE RATIO OF 6 TO 19	DISTANCE RATIO OF 6 TO 22	DISTANCE RATIO OF 6 TO 23	DISTANCE RATIO OF 7 TO 8
1 to 2	0.99740	0.99778	1.02204	0.85745	1.01468	1.19698
1 to 4	0.78317	0.79653	1.00589	0.79836	1.10454	1.09074
1 to 5	0.72909	0.84580	0.86917	0.96044	0.93408	1.06406
1 to 6	0.90611	0.88428	1.00164	0.79601	1.05653	1.07579
2 to 4	0.78521	0.79830	0.98420	0.93109	1.08856	0.91124
2 to 5	0.73099	0.84768	0.85042	1.12012	0.92056	0.88896
2 to 6	0.90847	0.88625	0.98004	0.92835	1.04124	0.89876
4 to 5	0.93095	1.06186	0.86407	1.20303	0.84567	0.97554
4 to 6	1.15698	1.11017	0.99578	0.99706	0.95653	0.98630
5 to 6	1.24280	1.04550	1.15242	0.82880	1.13109	1.01103

SESSIONS	DISTANCE RATIO OF 7 TO 13	DISTANCE RATIO OF 7 TO 14	DISTANCE RATIO OF 7 TO 15	DISTANCE RATIO OF 7 TO 16	DISTANCE RATIO OF 7 TO 17	DISTANCE RATIO OF 7 TO 18
1 to 2	1.08508	1.08957	0.92726	0.99461	0.97280	1.05626
1 to 4	1.01536	0.96216	0.87819	0.75769	0.79145	0.92849
1 to 5	0.94349	0.88850	0.91033	0.70904	0.73653	0.85925
1 to 6	0.95188	0.99144	0.87960	0.93061	0.90768	0.96628
2 to 4	0.93575	0.88306	0.94707	0.76180	0.81358	0.87903
2 to 5	0.86951	0.81546	0.98174	0.71288	0.75712	0.81348
2 to 6	0.87725	0.90994	0.94860	0.93565	0.93306	0.91481
4 to 5	0.92922	0.92344	1.03660	0.93579	0.93060	0.92543
4 to 6	0.93748	1.03043	1.00161	1.22821	1.14686	1.04070
5 to 6	1.00890	1.11586	0.96624	1.31249	1.23239	1.12456

SESSIONS	DISTANCE RATIO OF 7 TO 9	DISTANCE RATIO OF 7 TO 22	DISTANCE RATIO OF 7 TO 23	DISTANCE RATIO OF 8 TO 18	DISTANCE RATIO OF 8 TO 19	DISTANCE RATIO OF 11 TO 12
1 to 2	0.93096	1.01183	0.86432	1.00439	1.04295	0.95775
1 to 4	0.87764	1.00753	0.91269	0.91580	0.92082	0.83515
1 to 5	0.86081	0.92337	0.99831	0.84268	0.90556	0.98955
1 to 6	0.90620	0.94968	0.95796	0.91850	0.98937	1.07367
2 to 4	0.94272	0.99575	1.05596	0.91179	0.88290	0.87199
2 to 5	0.92464	0.91258	1.15502	0.83899	0.86826	1.03321
2 to 6	0.97341	0.93858	1.10834	0.91448	0.94863	1.12104
4 to 5	0.98082	0.91647	1.09380	0.92016	0.98343	1.18489
4 to 6	1.03255	0.94259	1.04960	1.00295	1.07445	1.28561
5 to 6	1.05274	1.02850	0.95958	1.08998	1.09256	1.08501

SESSIONS	DISTANCE RATIO OF 11 TO 13	DISTANCE RATIO OF 11 TO 14	DISTANCE RATIO OF 11 TO 15	DISTANCE RATIO OF 11 TO 16	DISTANCE RATIO OF 11 TO 17	DISTANCE RATIO OF 11 TO 18
1 to 2	0.97842	1.29426	1.03951	0.89790	0.92896	1.30245
1 to 4	0.94568	1.37232	0.98751	0.63768	0.57248	1.13015
1 to 5	1.01615	1.14623	1.01503	0.69034	0.59506	1.01168
1 to 6	1.37582	0.73927	1.07682	1.07587	0.89623	0.94451
2 to 4	0.96654	1.06031	0.94997	0.71019	0.61626	0.86771
2 to 5	1.03855	0.88562	0.97645	0.76884	0.64057	0.77675
2 to 6	1.40616	0.57119	1.03588	1.19821	0.96478	0.72518
4 to 5	1.07451	0.83525	1.02787	1.08258	1.03945	0.89517
4 to 6	1.45484	0.53870	1.09044	1.68717	1.56554	0.83574
5 to 6	1.35395	0.64496	1.06087	1.55847	1.50612	0.93361

SESSIONS	DISTANCE RATIO OF 11 TO 19	DISTANCE RATIO OF 11 TO 22	DISTANCE RATIO OF 11 TO 23	DISTANCE RATIO OF 12 TO 13	DISTANCE RATIO OF 12 TO 14	DISTANCE RATIO OF 12 TO 15
1 to 2	0.98927	1.31522	1.01162	0.93627	1.01849	1.72604
1 to 4	0.90301	1.04700	0.94123	0.74839	0.85894	1.65077
1 to 5	0.92045	0.99890	0.94542	0.96500	0.97468	1.18630
1 to 6	1.01307	0.99928	0.96248	0.88538	0.96643	1.25304
2 to 4	0.91280	0.79607	0.93042	0.79933	0.84335	0.95639
2 to 5	0.93043	0.75950	0.93457	1.03068	0.95699	0.68730
2 to 6	1.02406	0.75979	0.95143	0.94565	0.94889	0.72596
4 to 5	1.01931	0.95406	1.00445	1.28944	1.13475	0.71864
4 to 6	1.12188	0.95443	1.02257	1.18306	1.12514	0.75907
5 to 6	1.10062	1.00038	1.01804	0.91750	0.99153	1.05626

SESSIONS	DISTANCE RATIO OF 12 TO 16	DISTANCE RATIO OF 12 TO 17	DISTANCE RATIO OF 12 TO 18	DISTANCE RATIO OF 12 TO 19	DISTANCE RATIO OF 12 TO 22	DISTANCE RATIO OF 12 TO 23
1 to 2	0.84169	0.79145	1.00895	1.22604	1.05096	1.16173
1 to 4	0.50909	0.64853	0.86249	1.21855	0.90762	1.01625
1 to 5	0.51095	0.66883	0.95724	0.87718	0.98557	0.91205
1 to 6	0.93989	1.03835	1.02251	0.95719	1.01208	0.87830
2 to 4	0.60485	0.81942	0.85483	0.99389	0.86362	0.87478
2 to 5	0.60705	0.84506	0.94875	0.71546	0.93779	0.78508
2 to 6	1.11666	1.31195	1.01343	0.78071	0.96301	0.75603
4 to 5	1.00364	1.03130	1.10986	0.71985	1.08588	0.89747
4 to 6	1.84619	1.60108	1.18553	0.78551	1.11509	0.86425
5 to 6	1.83949	1.55249	1.06818	1.09121	1.02689	0.96299

SESSIONS	DISTANCE RATIO OF 13 TO 14	DISTANCE RATIO OF 13 TO 15	DISTANCE RATIO OF 13 TO 16	DISTANCE RATIO OF 13 TO 17	DISTANCE RATIO OF 13 TO 18	DISTANCE RATIO OF 13 TO 19
1 to 2	1.08416	1.10956	0.67028	0.55088	1.06505	1.00609
1 to 4	0.98385	1.03282	0.30377	0.27026	0.96833	0.88571
1 to 5	1.00071	1.02962	0.29330	0.25149	0.96777	0.88604
1 to 6	1.00684	0.97462	0.69315	0.49797	1.13250	0.89363
2 to 4	0.90748	0.93084	0.45320	0.49060	0.90919	0.88035
2 to 5	0.92303	0.92796	0.43758	0.45652	0.90866	0.88068
2 to 6	0.92868	0.87839	1.03411	0.90395	1.06333	0.88823
4 to 5	1.01714	0.99690	0.96555	0.93054	0.99942	1.00037
4 to 6	1.02336	0.94365	2.28182	1.84255	1.16953	1.00894
5 to 6	1.00612	0.94658	2.36323	1.98009	1.17022	1.00857

SESSIONS	DISTANCE RATIO OF 14 TO 15	DISTANCE RATIO OF 14 TO 16	DISTANCE RATIO OF 14 TO 17	DISTANCE RATIO OF 14 TO 18	DISTANCE RATIO OF 14 TO 19	DISTANCE RATIO OF 15 TO 16
1 to 2	1.04856	0.97957	1.00383	0.85987	1.00818	1.07068
1 to 4	0.94730	0.72319	0.68552	0.74766	0.88955	0.73794
1 to 5	0.97178	0.74017	0.67857	0.70161	0.89475	0.66379
1 to 6	0.98148	0.90214	0.79661	0.80128	0.94238	1.03012
2 to 4	0.90343	0.73827	0.68290	0.86950	0.88233	0.68923
2 to 5	0.92677	0.75561	0.67598	0.81595	0.88749	0.61997
2 to 6	0.93602	0.92096	0.79357	0.93186	0.93473	0.96211
4 to 5	1.02584	1.02348	0.98987	0.93841	1.00585	0.89952
4 to 6	1.03608	1.24745	1.16206	1.07172	1.05940	1.39593
5 to 6	1.00998	1.21883	1.17395	1.14206	1.05324	1.55186

SESSIONS	DISTANCE RATIO OF 15 TO 17	DISTANCE RATIO OF 15 TO 18	DISTANCE RATIO OF 15 TO 19	DISTANCE RATIO OF 16 TO 17	DISTANCE RATIO OF 16 TO 18	DISTANCE RATIO OF 16 TO 19
1 to 2	0.98290	1.03819	0.87721	0.61861	1.00012	1.00663
1 to 4	0.84116	0.94116	0.70638	1.54364	0.78801	0.72798
1 to 5	0.76327	0.94960	0.58808	1.80428	0.81226	0.68595
1 to 6	1.05408	1.01769	0.84765	1.74614	1.00891	0.94493
2 to 4	0.85580	0.90654	0.80526	2.49534	0.78791	0.72319
2 to 5	0.77655	0.91467	0.67040	2.91666	0.81216	0.68143
2 to 6	1.07241	0.98025	0.96630	2.82269	1.00878	0.93870
4 to 5	0.90740	1.00897	0.83252	1.16884	1.03078	0.94226
4 to 6	1.25312	1.08131	1.19999	1.13119	1.28032	1.29800
5 to 6	1.38100	1.07170	1.44139	0.96778	1.24209	1.37755

SESSIONS	DISTANCE RATIO OF 16 TO 20	DISTANCE RATIO OF 16 TO 21	DISTANCE RATIO OF 17 TO 18	DISTANCE RATIO OF 17 TO 19	DISTANCE RATIO OF 17 TO 20	DISTANCE RATIO OF 17 TO 21
1 to 2	1.06433	1.08620	1.04357	0.93587	1.08054	0.99046
1 to 4	0.72104	0.73109	0.74489	0.82409	0.69297	0.82463
1 to 5	0.71446	0.64545	0.74048	0.79243	0.66586	0.73369
1 to 6	0.97066	0.96022	0.90455	0.99384	0.84500	0.96650
2 to 4	0.67746	0.67307	0.71379	0.88056	0.64132	0.83258
2 to 5	0.67128	0.59423	0.70957	0.84674	0.61623	0.74075
2 to 6	0.91199	0.88402	0.86678	1.06194	0.78202	0.97581
4 to 5	0.99087	0.88286	0.99408	0.96159	0.96087	0.88971
4 to 6	1.34619	1.31342	1.21433	1.20599	1.21939	1.17204
5 to 6	1.35859	1.48768	1.22157	1.25416	1.26904	1.31732

SESSIONS	DISTANCE RATIO OF 18 TO 19	DISTANCE RATIO OF 18 TO 20	DISTANCE RATIO OF 19 TO 21	DISTANCE RATIO OF 20 TO 22	DISTANCE RATIO OF 21 TO 23
1 to 2	1.00459	0.88294	0.99508	0.99554	0.94963
1 to 4	0.89108	0.86287	1.14445	0.88852	0.83800
1 to 5	0.88965	0.69761	0.78232	0.86736	0.82839
1 to 6	0.97840	0.83562	0.98386	0.96237	0.84767
2 to 4	0.88701	0.97727	1.15010	0.89250	0.88246
2 to 5	0.88559	0.79010	0.78619	0.87125	0.87233
2 to 6	0.97394	0.94641	0.98872	0.96668	0.89263
4 to 5	0.99840	0.80848	0.68358	0.97619	0.98853
4 to 6	1.09799	0.96842	0.85968	1.08311	1.01153
5 to 6	1.09976	1.19783	1.25762	1.10954	1.02327

**APPENDIX G**  
**SUBJECT SESSION RECORD**

**APPENDIX G**

**SUBJECT SESSION RECORD**

SUBJECT	SESSION	LATEST DATE	WEEKS PREGNANT	SESSION COMPLETED	WEEKS PREGNANT
2	1	baseline session	baseline session	17 Jan 97	4 weeks
	2	5 May 97	20 weeks	30 Apr 97	19 weeks
	3	30 Jun, 7 Jul	28-29 weeks	30 Jun 97	28 weeks
	4	28 Jul, 4 Aug	32-33 weeks		
	5	1 Sep, 8 Sep	37-38 weeks		
	6				
3	1	baseline session	baseline session	21 Jan 97	9 weeks
	2	8 Apr 97	20 weeks	7 May 97	24 weeks
	3	3 Jun, 10 Jun	28-29 weeks	10 Jun 97	29 weeks
	4	1 Jul, 8 Jul	32-33 weeks	2 Jul 97	32 weeks
	5	5 Aug, 12 Aug	37-38 weeks		
	6				
4	1	baseline session	baseline session	22 Jan 97	16 weeks
	2	19 Feb 97	20 weeks	19 Feb 97	20 weeks
	3	16 Apr, 23 Apr	28-29 weeks	scanner down	scanner down
	4	14 May, 21 May	32-33 weeks	14 May 97	32 weeks
	5	18 Jun, 25 Jun	37-38 weeks	23 Jun 97	8 weeks
	6	10 Jul 97	2 weeks	10 Jul 97	2 weeks
6	1	baseline session	baseline session	25 Jan 97	12 weeks
	2	22 Mar 97	20 weeks	8 Mar 97	18 weeks
	3	17 May, 24 May	28-29 weeks	31 May 97	30 weeks
	4	14 Jun, 21 Jun	32-33 weeks	21 Jun 97	33 weeks
	5	19 Jul, 26 Jul	37-38 weeks		
	6				
7	1	baseline session	baseline session	27 Jan 97	10 weeks
	2	7 Apr 97	20 weeks	1 May 97	23 weeks
	3	2 Jun, 9 Jun	28-29 weeks	13 Jun 97	29 weeks
	4	30 Jun, 7 Jul	23-33 weeks	10 Jul 97	33 weeks
	5	4 Aug, 11 Aug	37-38 weeks		
	6				
8	1	baseline session	baseline session	29 Jan 97	8 weeks
	2	23 Apr 97	20 weeks	1 May 97	21 weeks

SUBJECT	SESSION	LATEST DATE	WEEKS PREGNANT	SESSION COMPLETED	WEEKS PREGNANT
	3	18 Jun, 25 Jun	28-29 weeks	20 Jun 97	28 weeks
	4	16 Jul, 23 Jul	32-33 weeks	7 Jul 97	31 weeks
	5	20 Aug, 27 Aug	37-38 weeks		
	6				
10	1	baseline session	baseline session	31 Jan 97	9.5 weeks
	2	14 Apr 97	20 weeks	8 May 97	23 weeks
	3	2 Jun, 9 Jun	28-29 weeks	6 Jun 97	28 weeks
	4	30 Jun, 7 Jul	32-33 weeks	10 Jul 97	33 weeks
	5	4 Aug, 11 Aug	37-38 weeks		
	6				
11	1	baseline session	baseline session	31 Jan 97	9 weeks
	2	18 Apr 97	20 weeks	1 May 97	22 weeks
	3	13 Jun, 20 Jun	28-29 weeks	13 Jun 97	28 weeks
	4	11 Jul, 18 Jul	32-33 weeks	10 Jul 97	32 weeks
	5	15 Aug, 22 Aug	37-38 weeks		
	6				
15	1	baseline session	baseline session	7 Feb 97	8 weeks
	2	2 May 97	20 weeks	7 May 97	20 weeks
	3	27 Jun, 4 Jul	28-29 weeks	1 Jul 97	28 weeks
	4	25 Jul, 1 Aug	32-33 weeks		
	5	29 Aug, 5 Sep	37-38 weeks		
	6				
16	1	baseline session	baseline session	10 Feb 97	8 weeks
	2	28 Apr 97	20 weeks	2 May 97	20 weeks
	3	23 Jun, 30 Jun	28-29 weeks	23 Jun 97	28 weeks
	4	21 Jul, 28 Jul	32-33 weeks		
	5	25 Aug, 1 Sep	37-38 weeks		
	6				
17	1	11 Feb 97	baseline session	11 Feb 97	7 weeks
	2	13 May 97	20 weeks	27 May 97	22 weeks
	3	7 Jul, 14 Jul	28-29 weeks	7 Jul 97	28 weeks
	4	4 Aug, 11 Aug	32-33 weeks		
	5	8 Sep, 15 Sep	37-38 weeks		
	6				
18	1	baseline session	baseline session	13 Feb 97	6 weeks

SUBJECT	SESSION	LATEST DATE	WEEKS PREGNANT	SESSION COMPLETED	WEEKS PREGNANT
	2	21 May 97	20 weeks	15 May 97	19 weeks
	3	17 Jul, 24 Jul	28-29 weeks		
	4	14 Aug, 21 Aug	32-33 weeks		
	5	18 Sep, 25 Sep	37-38 weeks		
	6				
20	1	baseline session	baseline session	18 Feb 97	9 weeks
	2	5 May 97	20 weeks	23 May 97	22 weeks
	3	30 Jun, 7 Jul	28-29 weeks	on vacation	on vacation
	4	28 Jul, 4 Aug	32-33 weeks		
	5	8 Sep, 15 Sep	37-38 weeks		
	6				
21	1	baseline session	baseline session	21 Feb 97	9 weeks
	2	5 May 97	20 weeks	21 May 97	22 weeks
	3	30 Jun, 7 Jul	28-29 weeks		
	4	28 Jul, 4 Aug	32-33 weeks		
	5	1 Sep, 8 Sep	37-38 weeks		
	6				
22	1	baseline session	baseline session	25 Feb 97	6 weeks
	2	2 Jun 97	20 weeks	2 Jun 97	20 weeks
	3	28 Jul, 4 Aug	28-29 weeks		
	4	25 Aug, 1 Sep	32-33 weeks		
	5	29 Sep, 6 Oct	37-38 weeks		
	6				
24	1	baseline session	baseline session	6 Mar 97	6 weeks
	2	12 Jun 97	20 weeks	12 Jun 97	20 weeks
	3	7 Aug, 14 Aug	28-29 weeks		
	4	4 Sep, 11 Sep	32-33 weeks		
	5	9 Oct, 16 Oct	37-38 weeks		
	6				
27	1	baseline session	baseline session	13 Mar 97	9 weeks
	2	29 May 97	20 weeks	9 Jun 97	21 weeks
	3	24 Jul, 31 Jul	28-29 weeks		
	4	21 Aug, 28 Aug	32-33 weeks		
	5	25 Sep, 2 Oct	37-38 weeks		
	6				

SUBJECT	SESSION	LATEST DATE	WEEKS PREGNANT	SESSION COMPLETED	WEEKS PREGNANT
28	1	baseline session	baseline session	14 Mar 97	6 weeks
	2	18 Jun 97	20 weeks	27 Jun 97	21 weeks
	3	13 Aug, 20 Aug	28-29 weeks		
	4	10 Sep, 17 Sep	32-33 weeks		
	5	15 Oct, 22 Oct	37-38 weeks		
	6				
29	1	baseline session	baseline session	1 Apr 97	9 weeks
	2	17 Jun 97	20 weeks		
	3	12 Aug, 19 Aug	28-29 weeks		
	4	9 Sep, 16 Sep	32-33 weeks		
	5	14 Oct, 21 Oct	37-38 weeks		
	6				
30	1	baseline session	baseline session	22 Apr 97	7 weeks
	2	22 Jul 97	20 weeks		
	3	16 Sep, 23 Sep	28-29 weeks		
	4	14 Oct, 21 Oct	32-33 weeks		
	5	18 Nov, 25 Nov	37-38 weeks		
	6				
32	1	baseline session	baseline session	29 Apr 97	12 weeks
	2	24 Jun 97	20 weeks	7 Jul 97	22 weeks
	3	19 Aug, 26 Aug	28-29 weeks		
	4	16 Sep, 23 Sep	32-33 weeks		
	5	21 Oct, 28 Oct	37-38 weeks		
	6				
33	1	baseline session	baseline session	30 Apr 97	10 weeks
	2	4 Jul 97	20 weeks	2 Jul 97	20 weeks
	3	29 Aug, 5 Sep	28-29 weeks		
	4	26 Sep, 3 Oct	32-33 weeks		
	5	31 Oct, 7 Nov	37-38 weeks		
	6				
34	1	baseline session	baseline session	17 May 97	10 weeks
	2	26 Jul 97	20 weeks		
	3	20 Sep, 27 Sep	28-29 weeks		
	4	18 Oct, 25 Oct	32-33 weeks		
	5	22 Nov, 29 Nov	37-38 weeks		
	6				

SUBJECT	SESSION	LATEST DATE	WEEKS PREGNANT	SESSION COMPLETED	WEEKS PREGNANT
35	1	baseline session	baseline session	22 May 97	6 weeks
	2	28 Aug 97	20 weeks		
	3	23 Oct, 30 Oct	28-29 weeks		
	4	20 Nov, 27 Nov	32-33 weeks		
	5	25 Dec, 1 Jan	37-38 weeks		
	6				