To the Graduate Council:

I am submitting herewith a thesis written by Lisa R. Vickers entitled "The Prediction Equations of the Male and Female Chest Wall Thicknesses for Measuring Actinides within the Lungs Using HPGe Detectors." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science in Nuclear Engineering.

Lawrence F. Miller

Dr. L.F. Miller, Major Prof. Nuc Eng

We have read this thesis
and recommend its acceptance:

Peter G. Groer

Dr. P.G. Groer, Prof. Nuclear Engineering

Paul N. Stevens

Dr. P.N. Stevens, Prof. Nuclear Engineering

Accepted for the Council:

Lev Minkel

Associate Vice Chancellor
and Dean of The Graduate School

# The Prediction Equations of the Male and Female Chest Wall Thicknesses for Measuring Actinides within the Lungs Using HPGe Detectors

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Master of Science

Degree

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Lisa R. Vickers

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## ABSTRACT

This research was to empirically derive the male and female chest wall thickness (CWT) prediction equations, using ultrasonic technology and a two-, three- or six-detector hyperpure germanium (HPGe) array, for measuring actinides within the lungs. Presently, there is not a gender-specific CWT prediction equation derived for HPGe detection systems. The majority of the U.S. Department of Energy lung counting facilities are using HPGe detection systems for routine lung counting measurements and not the two-detector phoswich system. The current CWT equation was derived for photons with energy greater than 100 keV using a two-detector, 12.7-cm diameter phoswich lung counting system, male subjects only, positioned supine, and without measuring, the compositional thicknesses of the intercostal tissue (between the ribs) which are the muscle and adipose tissues. The lung areas observed by the phoswich and HPGe array detection systems are significantly different. The intercostal tissues observed by the HPGe arrays are presumed to be composed of more muscle tissue than the phoswich array due to the position of the HPGe detectors located closer to the sternum and encompassing a much smaller area of intercostal tissue. Therefore, the current CWT equation is presumed to be predicting CWT values which are less attenuating, thus, leading to overestimates in activity (nCi) reported within the lungs. Also, the current CWT equation is applied to both genders. According to the data specifications in ICRP75 Publication 23, the current CWT equation is presumed to be not applicable for estimating the female CWT due to the anatomical difference in male and female which is the breast tissue. Therefore, this paper empirically derives the male and female CWT prediction equations, using 33 male and 37 female subjects, ultrasonic technology and a two-, three- or six-detector HPGe array, for measuring actinides within the lungs.

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# CHAPTER 1

## INTRODUCTION

The Oak Ridge National Laboratory Whole Body Counting Laboratory (ORNL WBCL) routinely performs in vivo monitoring (lung counting) on radiation workers who have a potential for internal exposure to radioactive contamination deposited in the lungs via the inhalation pathway. Personnel may be exposed to small quantities of many actinides, some of which are low energy photon emitters such as $^{239}Pu$ with an average 17 keV X-ray from the uranium $L_{\alpha}$, $L_{\beta}$ and $L_{\gamma}$ X-ray series (13.6, 17.2 and 20.2 keV, respectively) and $^{241}Am$ 59.5 keV gammas. Low energy photons are significantly attenuated by the chest wall tissue which is composed primarily of adipose, muscle and bone (ribs/sternum).

The anterior thorax area observed, using a typical two-detector, 12.7-cm diameter NaI-CsI phoswich system, during a lung count, is approximately 45% bone in which there is virtually no transmission of low energy photons, therefore, photon detection is dependent on the flux emerging through the intercostal tissues (between the ribs) (Ne78[1]). However, the intercostal tissue, which is composed primarily of adipose and muscle, significantly attenuates the photons as well. The half-value thickness for attenuation of 17-keV photons is approximately 6 mm for muscle, 12 mm for adipose and 0.3 mm for bone, consequently, muscle attenuates the 17 keV photon by a factor of two greater than the attenuation by adipose tissue. For the 59.5 keV gamma, adipose and muscle tissue attenuate nearly the same, therefore, the thickness of each tissue is not critical to quantify. However, for 17-keV photons, it is critical to quantify the tissue thicknesses, therefore, ultrasonic technology is employed to estimate the thickness of the muscle and adipose tissue of the total chest wall

thickness (CWT) (Ka93). The accurate and precise estimation of the thickness of the intercostal tissues overlying the lungs is requisite for assessing the dose imparted from low energy photons. Each millimeter error in estimating the CWT causes an average of 10% error in the detector efficiency calibration for plutonium using a two- or three-detector hyperpure germanium (HPGe) array (71 mm diameter), or a typical two-detector, 12.7-cm diameter NaI-CsI phoswich lung counting system (Kr90,K25,ORNL94).

The uncertainties in assessing plutonium contamination in the lungs are very large; most significantly, the unknown distribution of activity in the lungs which may lead to an uncertainty of $\pm$ 70% (Su82), however, the detector efficiency calibration assumes a uniform distribution of activity in the phantom lungs. The CWT estimate, using the phoswich detection system, should be within $\pm$ 3 mm to reduce the $\pm$ 70% uncertainty in the final estimate of plutonium in the lungs to approximately $\pm$ 25% (Su82).

The typical CWT equations, which are used by the majority of the U.S. Department of Energy (DOE) lung counting facilities, were empirically derived with the use of ultrasonic technology and a typical two-detector, 12.7-cm diameter NaI-CsI phoswich lung counting system, for detection of photons with energies above 100 keV and only male subjects positioned supine. The CWT equations only measured the total intercostal tissue thickness and did not account for the compositional tissue thicknesses of adipose and muscle. The uncertainty in CWT (about 6 mm) associated with these equations is unacceptable when measuring and quantifying low energy X-ray emitters (Kr90). The CWT equations were derived with male subjects only and are used for estimating the female CWT. The CWT equations are presumed to be an incorrect estimation of the female CWT due to the difference in data specifications of the Reference Male and Reference Female of ICRP 75 Publication 23 (ICRP75). Therefore, the female CWT equation needs to be derived with

female subjects. The chest wall thickness observed by an array of two-, three- or six-HPGe detectors is assumed to be composed of more muscle tissue than the CWTs observed by the phoswich two-detector array due to the tissue composition observed by the HPGe detectors tangential to the thoracic midline or sternum, thus, yielding a more attenuating chest wall thickness (Ka93). The HPGe two- and three-detector array active areas are less than the phoswich two-detector active area by factors of three and two, respectively, depicting the smaller regions of chest area observed for ultrasonic and lung counting measurements. The ultrasonic measurements for the phoswich system are made in different locations of the chest area than the HPGe system, thus, yielding a difference in CWT estimates. The majority of the DOE lung counting facilities are using HPGe detectors for routine lung counting measurements. Therefore, two CWT equations need to be derived applicable for the gender of the subject and HPGe detection array.

C.D. Berger and B.H. Lane (Be85), of the Oak Ridge National Laboratory, empirically derived a biometric estimation of chest wall thickness for 77 female subjects. The Berger and Lane biometric equation is the only empirically derived estimation of the female chest wall thickness using female subjects. The biometric measurements recorded for each subject standing included the circumference of the abdomen, hips, right thigh, right calf, right upper and lower forearm, and chest (both standing and supine). Due to the requirement of recording each of these biometric measurements per subject for a routine lung counting measurement, it would be more efficient to estimate the female CWT using only biometrical data of weight and height. The need for such a simplified female CWT equation is one of the purposes of this paper which empirically derived the female CWT equation using ultrasonic technology and biometrical data of weight (kg) and height (cm) for 37 female subjects.

H.E. Palmer and G. Rieksts, of Pacific Northwest Laboratory in Richland, WA, made in vivo measurements of lung depositions in 10 female volunteers who had inhaled $^{92m}$Nb in England (Pa89). Palmer et al. (Pa89) reported the significant average increase in detection efficiency from the supine to reclined position (torso 45° from horizontal) as 108% for an array of six HPGe and 310% for a pair of phoswich detectors. In addition, the CWT was observed to be approximately 6 mm less in the reclined than supine position due to the tissues being pulled lower by gravity when positioned reclined rather than supine (Pa89). Therefore, the reclined position is the recommended subject position for routine lung counting measurements of male and female subjects (Pa89).

The CWT varies considerably over the regions viewed by the phoswich detectors. The CWT is usually thinnest close to the sternum. Typically, for the phoswich detector configuration and male subjects only, the CWT increases about 60% laterally from a position near the sternum to the outer edge of the region of interest, and increases about 15% transversely from the clavicles to the lower ribs. Consequently, the ultrasonic CWT measurements in the region of interest should be as representative, uniform, and dense as possible (Ka93). Figure 1-1 shows the comparison of the ORNL WBCL CWT ultrasonic measurements procedure for the phoswich and HPGe detectors. The measurements are made on the left and right lung areas for both procedures; only one lung area of measurements is shown for each procedure. Figure 1-2 shows the comparison of several in vivo facilities CWT ultrasonic measurements procedure for the phoswich to the ORNL WBCL HPGe array ultrasonic measurements procedure, which depicts the different measurement locations used to determine the CWT, and thus, is a factor in accounting for the difference in CWT values for the HPGe and phoswich ultrasonic measurements procedures.

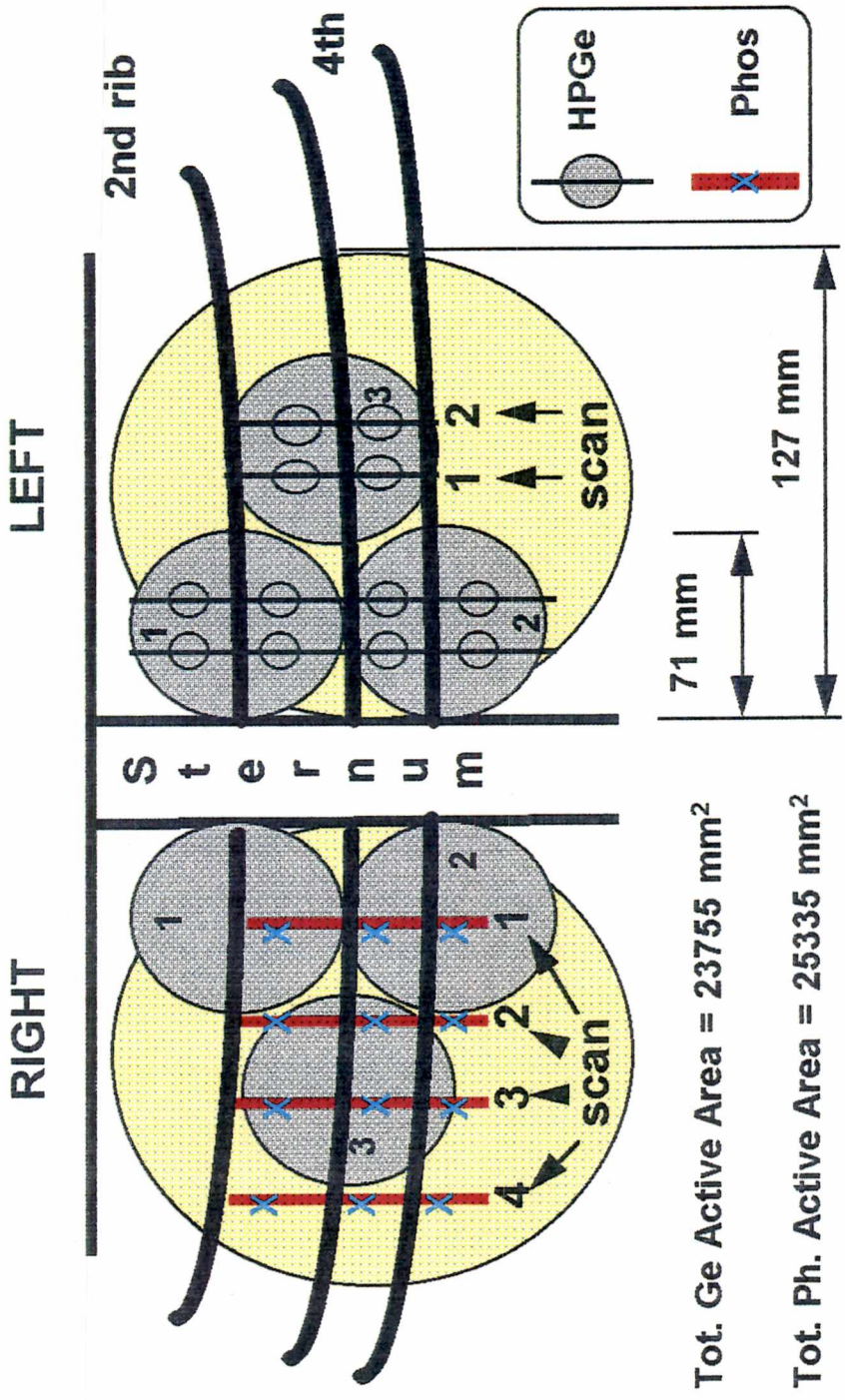



Figure 1-1. Comparison of the ORNL WBCL CWT Ultrasonic Measurements Procedure for the HPGe and Phoswich Detector Regions of Interest

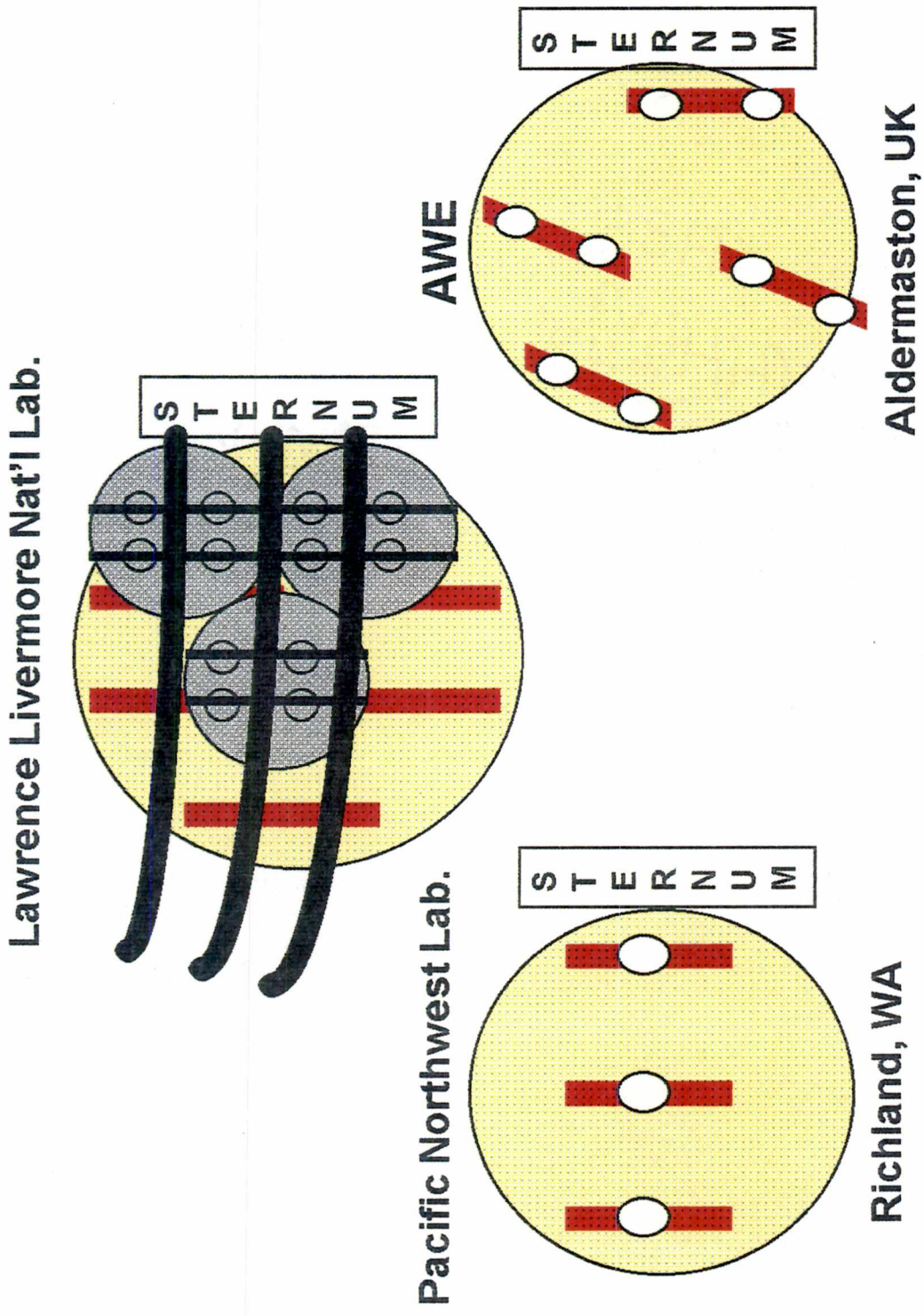



Figure 1-2. Comparison of the ORNL WBCL HPGe CWT Ultrasonic Measurements Procedure with the Phoswich CWT Ultrasonic Measurements Procedure of Several In Vivo Facilities 1988-89 (Ka93)

## Purpose

The purpose of this research is to empirically derive the male and female chest wall thickness equations, with ultrasonic technology to measure the compositional thicknesses of the total CWT which are adipose and muscle, for detection of low energy photons (approximately 17-100 keV) using an array of two-, three- or six-HPGe detectors (71 mm diameter, each detector) with the subject in the reclined position, and biometrical data of weight (kg) and height (cm). Presently, these two equations are not published as derived by this paper. Furthermore, according to the data specifications of the Reference Male and Reference Female described in ICRP 75 Publication 23, the male CWT is composed of a greater percentage of muscle tissue than the female CWT, thus, yielding a more attenuating CWT; conversely, the female CWT is composed of a greater percentage of adipose tissue than the male CWT, thus, yielding a less attenuating CWT. Therefore, the current equations are presumed to be an overestimation of the female CWT and the activity (nCi) reported, consequently, the female CWT equation needs to be specifically derived using female subjects.

# CHAPTER 2

## TRANSMISSION OF ULTRASONIC WAVES

The sensation of sound is produced in the brain when the frequency is within the range of approximately 20-20,000 Hz. Sound waves of frequencies above approximately 20,000 Hz are called ultrasonic waves. An ultrasonic wave is a high frequency acoustic pressure wave transmitted through a medium (Mi77).

Ultrasonic wave propagation is dependent on the density of the medium. Reflected waves or echoes are produced whenever there is a change in acoustic impedance, that is at tissue boundaries and within inhomogeneous tissue structures (Su82). Higher the density of the medium, the faster and farther the waves will travel. The velocity of sound waves is a function of the elastic modulus and the density of the medium being traversed. The elastic modulus for sound waves traversing a liquid or gas is the bulk modulus (B) because a liquid and gas have no definite length or shape (Mi77). Longitudinal waves are of primary interest in ultrasonic measurements because they are the usual mode in liquid of which body tissue is primarily composed. In longitudinal waves, the particle motion oscillates parallel to the direction of the wave propagation. Transverse waves may occur in solids such as bone and have particle motion in the direction normal to the wave propagation (Si80).

The equation for the velocity of a sound (compression) wave is given by

$$v\ (m/s) = (B/d)^{1/2}, \tag{2-1}$$

where B = bulk modulus ($N/m^2$) and d = density ($kg/m^3$).

Table 2-1 presents the velocities (m/s) of sound traversing different biological tissue densities (Si80).

Table 2-1. Velocity of sound in biological materials.

| TISSUE | VELOCITY (m/s) |
|---|---|
| Water | 1525 |
| Soft Tissue | 1540* |
| Bone | 3380 |
| Aqueous | 1532 |
| Lens of Eye | 1640 |

*Assumed Average Velocity
Table from P.N.T. Well's Physical Principles of Ultrasonic Diagnosis, Academic Press, 1969.

High density media, such as the ribs and sternum, absorb the wave and produce transverse waves to the direction of the wave propagation, which do not echo to the transducer for processing and image production on the cathode ray tube (CRT). The low density media, such as adipose tissue, attenuate the wave propagation and longitudinally reflect the wave to the transducer for processing and image production on the CRT. Consequently, low density media, such as body fluids, adipose and muscle tissues produce better axial and lateral image resolution on the CRT than high density media, such as the rib and sternum bones, which appear as dark shadows indicating a location of no-echo (Su82). Ultrasonic frequencies within the range of two to five MHz are required for measurements of chest wall thickness and composition. This research performed chest wall thickness measurements with an ultrasonic frequency of 3.5 MHz.

# CHAPTER 3

## PRODUCTION OF CRT IMAGE

The linear array of transducers contained within the single probe consists of certain natural crystals which transmit acoustic pressure waves when an electrical potential is applied. The crystals can also receive echo acoustic pressure waves which induce an electrical potential. The induced electrical potential appears as a radio-frequency pulse signal, and is amplified, processed and displayed on the CRT. The effect of the transducer crystals transmitting and receiving acoustic pressure waves is called the piezoelectric principle (Si80).

The distance traversed by the ultrasonic waves can be calculated by the known velocity of sound in tissue (1540 m/s) and the time elapsed since transmission to reception can be measured. The equation for calculating the distance is given by

$$d = vt/2, \tag{3-1}$$

where d = distance (m), v = velocity (m/s) and t = time (s).

The amplitude of the echoed wave is correlated with display intensity or brightness on the CRT, therefore, large amplitude pulses are from the lowest density medias and displayed the brightest. This type of image presentation is called the B-mode (Brightness-mode). The display image is rotated 90° clockwise from conventional television orientation (Si80).

# CHAPTER 4

## ATTENUATION OF PHOTONS

Monoenergetic photons are attenuated exponentially in a uniform target (Tu86). Low energy photon transmission in matter is governed statistically by the probability per unit distance traveled that it interacts predominantly by the physical process known as the photoelectric effect. The symbol $\mu$, expressed with the unit $cm^{-1}$, represents the statistical probability of photon interaction per unit distance traversed in a medium, and is called the total linear attenuation coefficient (compton scatter plus photoelectric effect). If there are n atoms per unit volume in a uniform medium then one can express this coefficient as:

$$\mu = n\sigma \ (cm^{-1}),$$

where $\sigma$ is called the microscopic cross section and has the dimension of area. The $\mu$ is defined for a narrow beam attenuation geometry of monoenergetic photons (Su82). The narrow-beam arrangement is configured such that any interaction, whether absorption or scattering, would remove a particle from any appreciable chance of detection, therefore, yielding detection only of the uncollided (non-interacting) photons (Ch84). The detector appears to the low energy photons to be a large distance away, thus, represents the assumption of narrow-beam attenuation geometry. The low energy photons detected by HPGe detectors are assumed to be the uncollided flux emerging from narrow-beam attenuation geometry due to a normally incident monogenergetic photon beam because the HPGe detectors operate most efficiently for low energy photons interacting by the photoelectric effect in the intrinsic or depleted region of the detector crystalline lattice.

The photoelectric effect interaction provides full energy deposition of the incident

photon which is characteristic of the source radionuclide, therefore, enabling detection and identification of the radionuclide. The choice of the total linear attenuation coefficient is not critical (Fr80). Table 4-1 shows the total linear attenuation coefficients for the 17- and 59.5- keV photons in human tissues.

Table 4-1. Total linear attenuation coefficients ($cm^{-1}$) for 17- and 59.5-keV photons in human tissues.

| Tissue | Density ($g/cm^3$) | $\mu_{total}$ 17-keV | $\mu_{total}$ 59.5-keV |
|---|---|---|---|
| Adipose | 0.92[1] | 0.57[2] | 0.171[1] |
| Muscle | 1.04[1] | 1.27[2] | 0.197[1] |
| Rib | 1.27[1] | 4.41[2] | 0.299[1] |
| 50Adp/50Mus | 0.98 | 0.92 | 0.184 |

Sources: [1]Sumerling, T.J.; Quant, S.P. "Measurements of the Human Anterior Chest Wall By Ultrasound and Estimates of Chest Wall Thickness for Use in Determination of Transuranic Nuclides in the Lung". *Radiation Protection Dosimetry*, 3, pp.203-310 (1982);
[2]Kruchten, D.A.; Anderson, A.L. "Improved Ultrasonic Measurement Techniques Applied to Assay of Pu and Other Transuranics in Lung". *Health Physics*, **59**, pp.117-123 (July 1990).

The exponential attenuation of monoenergetic photons in a narrow-beam attenuation geometry is described as follows: Consider a narrow beam of $N_0$ monoenergetic photons incident normally on a slab. As the beam penetrates the absorber, some photons interact and are scattered and some are absorbed. N(x) represents the number of photons that reach a depth of x without having interacted. The number that interact within the next small distance dx is proportional to N and to dx (Tu86), therefore, we may write

$$dN = -\mu N dx$$

$$\int dN/N = \int -\mu dx$$

$$\ln N(x) - \ln N_0 = -\mu x$$

$$\ln [N(x)/N_0] = -\mu x$$

$$N(x)/N_0 = e^{-\mu x}$$

$$N(x) = N_0 e^{-\mu x}$$

# CHAPTER 5

## ULTRASONIC MEASUREMENTS PROCEDURE

Prior to performing the ultrasonic measurements, a quality assurance (QA) verification is necessary. The ultrasonic system was factory calibrated and only requires QA checks to be performed prior to measurement operations. The QA check provides early detection of variations and/or degradations of the ultrasound unit performance and the geometric accuracy and resolution of the Imager II (CRT) prior to acquisition of chest wall thickness measurements. Typically, the procedure uses a soft tissue-like density material in which the velocity of sound is uniformly 1540 m/s within object, such as transparent lucite. The QA check utilized a 5.0 cm right-circular cylinder referred to as the American Institute of Ultrasound in Medicine (AIUM) Test Object with the velocity of ultrasonic waves within it measured at 1540 m/s $\pm$ 1%. The detailed QA procedure is described in Chapter 6 of (Si80).

Ultrasonic measurements were made with a Siemens Model 2300 PHO/SONIC Series 2000 Linear Array Dynamic Imaging System, B-mode display, with a single probe (linear array of transducers) operating at 3.5 MHz. The probe was acoustically coupled to the anterior thorax epidermal surface of the subject with a sonolucent gel, and calibrated for an average speed of sound in soft tissue at 1540 m/s. The cross-sectional thickness (mm) corresponding to the time separation between echoes from the epidermal surface and the tissue boundaries was read directly from the electronic calipers and displayed on the CRT as an integer value to within $\pm$ 1 mm.

This research analyzed the data collected of 33 male and 37 female subjects. Each subject was seated in a dental-style chair with the back-support at 45° counterclockwise from

the horizontal plane matching the position of a routine lung count. Six HPGe detector positions were outlined, using a template and water-soluble ink, on the anterior thorax of the subject, tangential to the sternum and clavicles. Two lateral ultrasonic scans, with two measurements through the center of the intercostal tissues were recorded per scan, for each detector position. A total of twelve scans and 24 recorded measurements were made per subject. Each measurement recorded the cross-sectional thicknesses (mm) of the adipose tissue as from the epidermal surface to the subcutaneous adipose-pectoral muscle interface, and the total tissue as from the epidermal surface to the pleural lining of the lung. The subtraction of the adipose-muscle interface from the total tissue yields the muscle tissue thickness (mm). Figure 5-1 shows the CWT ultrasonic measurement positions, Appendix A shows the format and data of each subject's measurements, and Figure 5-2 shows a typical CRT image of a lateral ultrasonic scan through the anterior thorax over the right lung in detector position R1 (Vi94). As shown in Figure 5-2, A, the anterior thorax epidermal surface; B, the subcutaneous adipose-muscle interface; C, the pleural lining of the lung interface; and D, two ribs, cast as acoustic shadows indicating a location of no ultrasonic wave echo to the transducer for image processing.

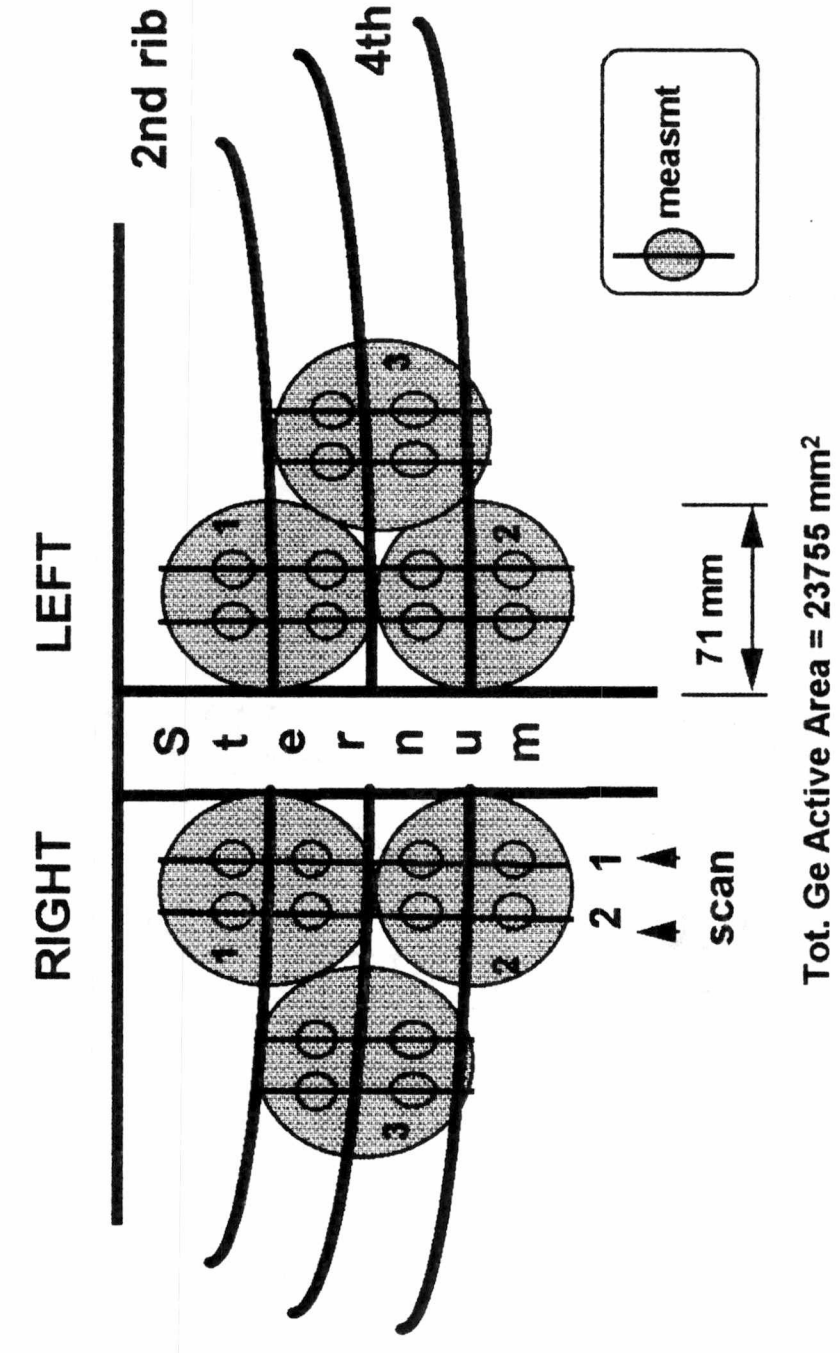



Figure 5-1. Ultrasonic CWT Measurement Locations for HPGe Detection System

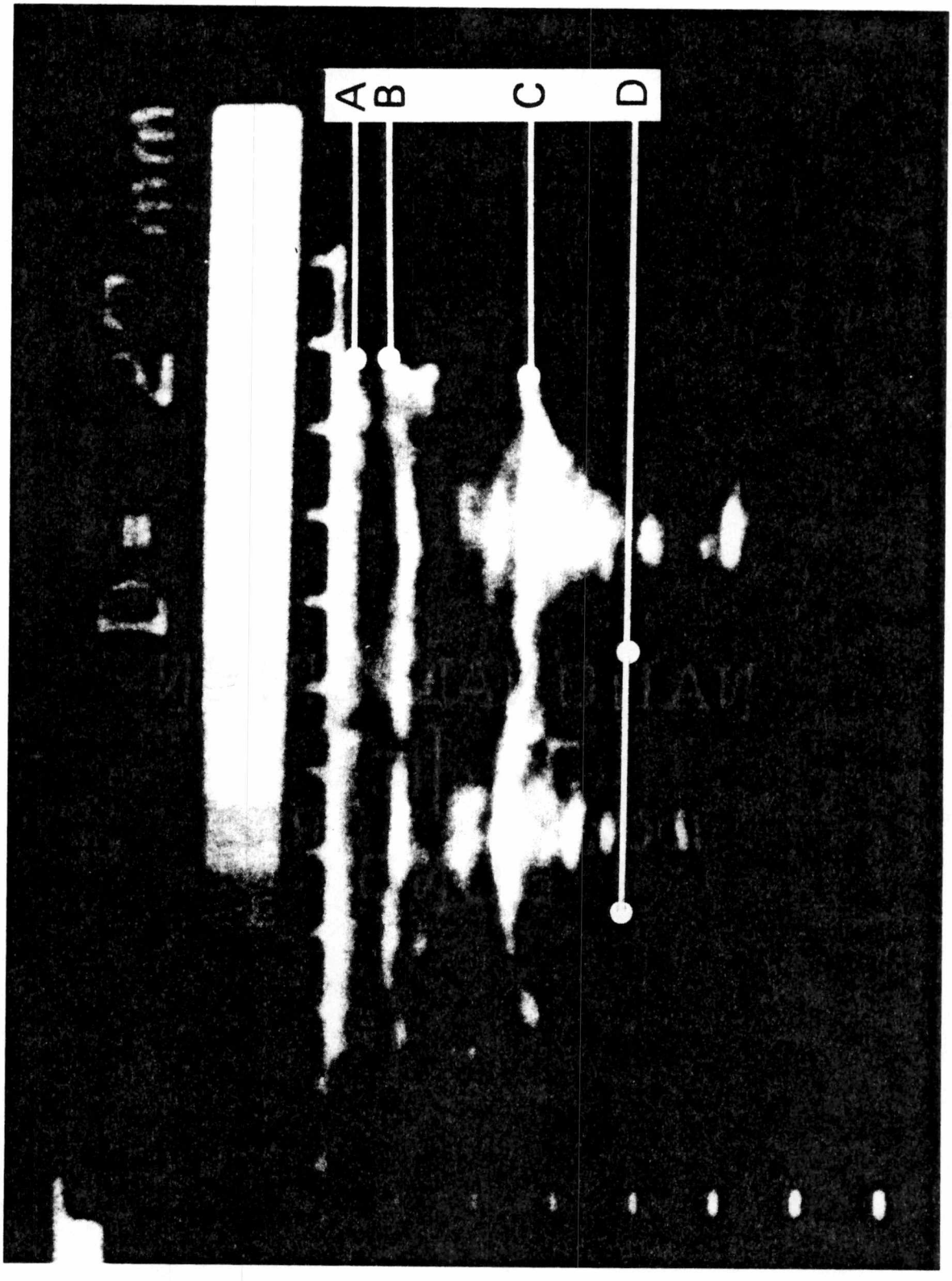



Figure 5-2. A typical CRT image of a lateral ultrasonic scan through the anterior thorax over the right lung in detector position R1

# CHAPTER 6

## DATA ANALYSIS

The photon emissions from within the lung are exponentially attenuated by the intercostal tissue, therefore, the average photon transmission should be calculated and related to an equivalent thickness x of soft tissue which would produce the same effective X-ray transmission as the measured thickness of the intercostal tissues as shown calculated by

$$I(x) = I_0 e^{-\mu x} \tag{6-1}$$

where I(x) is the photon fluence rate (photons/cm$^2$ sec) transmitted through x, the effective chest wall thickness, $I_0$ is the normally incident, monoenergetic photon fluence rate, and $\mu$ is the total linear attenuation coefficient applicable to the percent ratio of adipose to muscle by thickness of x. The CWT is the "effective" or "exponentially weighted" mean value of n independent, tissue thickness measurements and is given by

$$\text{EFF CWT (cm)} = -\mu_{50/50}^{-1} \ln \left[\left[\sum_{i=1}^{n} \exp -(\mu_a x_{ai} + \mu_m x_{mi})\right]^* n^{-1}\right] \tag{6-2}$$

where $\mu_{50/50}$, $\mu_a$ and $\mu_m$ are the total linear attenuation coefficients for 17- and 59.5 keV photons in adipose and muscle tissue, and $x_{ai}$ and $x_{mi}$ are the thicknesses of adipose and muscle tissue at each of n measurements. The mean effective CWT was normalized for the percent tissue composition of 50% muscle (by thickness) and 50% adipose to correlate to the calibration torso phantom chest wall overlay plates using $\mu_{50/50} = 0.92$ cm$^{-1}$.

The phoswich derived CWT equations calculated the effective CWT given by

$$\text{EFF CWT (cm)} = -\mu^{-1} \ln \left[ \left[ \sum_{i=1}^{n} \exp -(\mu\, t_i) \right] * n^{-1} \right] \qquad (6\text{-}3)$$

where $\mu$ is the total linear attenuation coefficient for 17-keV photons (De73,Fr80) and for greater than 100 keV photons (An83) in a uniform, effective thickness of soft tissue composed of 22% adipose and 78% muscle (Ne78[2]), and $t_i$ is the total intercostal tissue thickness measured from the surface of the epidermal interface to the pleural lining of the lung and does not account for the compositional thicknesses of adipose and muscle of the total CWT.

The mean effective CWT was calculated for three detector array configurations, (1) two-detector positions L1 and R1, (2) three-detector positions L1, R1 and R2, and (3) six-detector positions referred to as the total CWT. Only (1) and (2) detector configurations have efficiency calibration documentation because configurations (1) and (2) are the detector configurations in use at the K-25 Site Lung Counter and the ORNL WBCL, respectively.

The detector efficiency calibration, using the two-detector HPGe array for detection of $^{241}$Am 17.7 keV photons, is an exponential function of the CWT given by

$$\text{Efficiency} = a_1 * \exp(a_2 * \text{CWT}), \qquad (6\text{-}4)$$

where $a_1$ = 1.6397E-3 and $a_2$ = -1.0736 with a linear correlation coefficient of -0.99925; for detection of $^{241}$Am 59.5 keV photons,

$$\text{Efficiency} = a_1 * \exp(a_2 * \text{CWT}), \qquad (6\text{-}5)$$

where $a_1$ = 1.1963E-2 and $a_2$ = -3.9149E-1 with a linear correlation coefficient of -0.99220.

The detector efficiency calibration, using the three-detector HPGe array for detection of $^{239}$Pu 17.19 keV photons, is an exponential function of the CWT given by

$$\text{Efficiency} = a_1 * \exp(a_2 * \text{CWT}), \tag{6-6}$$

where $a_1$ = 4.40417E-3 and $a_2$ = -1.08342; for detection of $^{241}$Am 59.5 keV photons,

$$\text{Efficiency} = a_1 * \exp(a_2 * \text{CWT}), \tag{6-7}$$

where $a_1$ = 0.193944 and $a_2$ = -0.35428.

The arithmetic average AA CWT is simply the average of the actual, physical CWT ultrasonic measurements given by

$$\text{AA CWT (cm)} = \frac{\sum_{i=1}^{n} x_i}{n} \tag{6-8}$$

The arithmetic average CWT is typically less than the effective CWT. It is the thickness of tissue applied for photons of energy greater than 60 keV for which the total linear attenuation coefficients for adipose and muscle are approximately the same, therefore, the photon intensity is not significantly exponentially attenuated traversing the arithmetic average thickness, consequently, the CWT is calculated as the arithmetic average thickness for detection of photons greater than 60 keV (Su82).

**Male Data Analysis**

The following results derived for $^{239}$Pu 17-keV photons and the male total CWT relate to measurements using a standard technique for all 33 subjects. The regions of interest for the total CWT are most closely related to the phoswich regions of interest for derivation of the CWT, therefore, it is the array providing a CWT which is most comparable of the three

detector array configurations and consequently, the male total CWT equation was selected to use for comparison with the phoswich derived CWT equations; the same applies for the comparison of the female total CWT equation with the phoswich derived equations.

The mean effective chest wall thickness of 33 males was 3.82 cm with a standard deviation of $\pm$ 0.37 cm; individual results varied in range from 3.12 to 4.69 cm. The arithmetic average CWT was 3.20 cm for a measured total tissue composition of 33% adipose and 67% muscle. The tissue composition by percentage of adipose and muscle is approximately the same for each of the detector array configurations, indicating a uniform distribution of adipose and muscle throughout the measured regions of interest. Also, the average male chest area measured has minimal anatomical variation in chest structure laterally and transversely. Some exceptions were noted for male subjects who exercised routinely thus, had significant muscle thicknesses and variations in the chest areas measured. In addition, males who were overweight had significant adipose thicknesses and variations in the chest areas measured. Therefore, the same tissue composition of 33% adipose and 67% muscle was observed throughout the total chest area measured.

Although correlations with functions of height, weight and chest circumference have been analyzed, none have shown to be significantly better than the simple correlation with the ratio of weight to height (Fr80). In order to compare the data obtained in this study with several published information a similar analysis was performed. Linear regression analysis indicated that the data could be represented by the function

$$\text{CWT (cm)} = 4.3657(W/H) + 1.6476 \quad \text{(Vi94)}, \tag{6-9}$$

where W is the weight (kg), and H is the height (cm). This predicted CWT line is shown in Figure 6-1. In the absence of an ultrasonic measurement of chest wall thickness, this equation could be used to predict a value of CWT. The standard error at the 95%

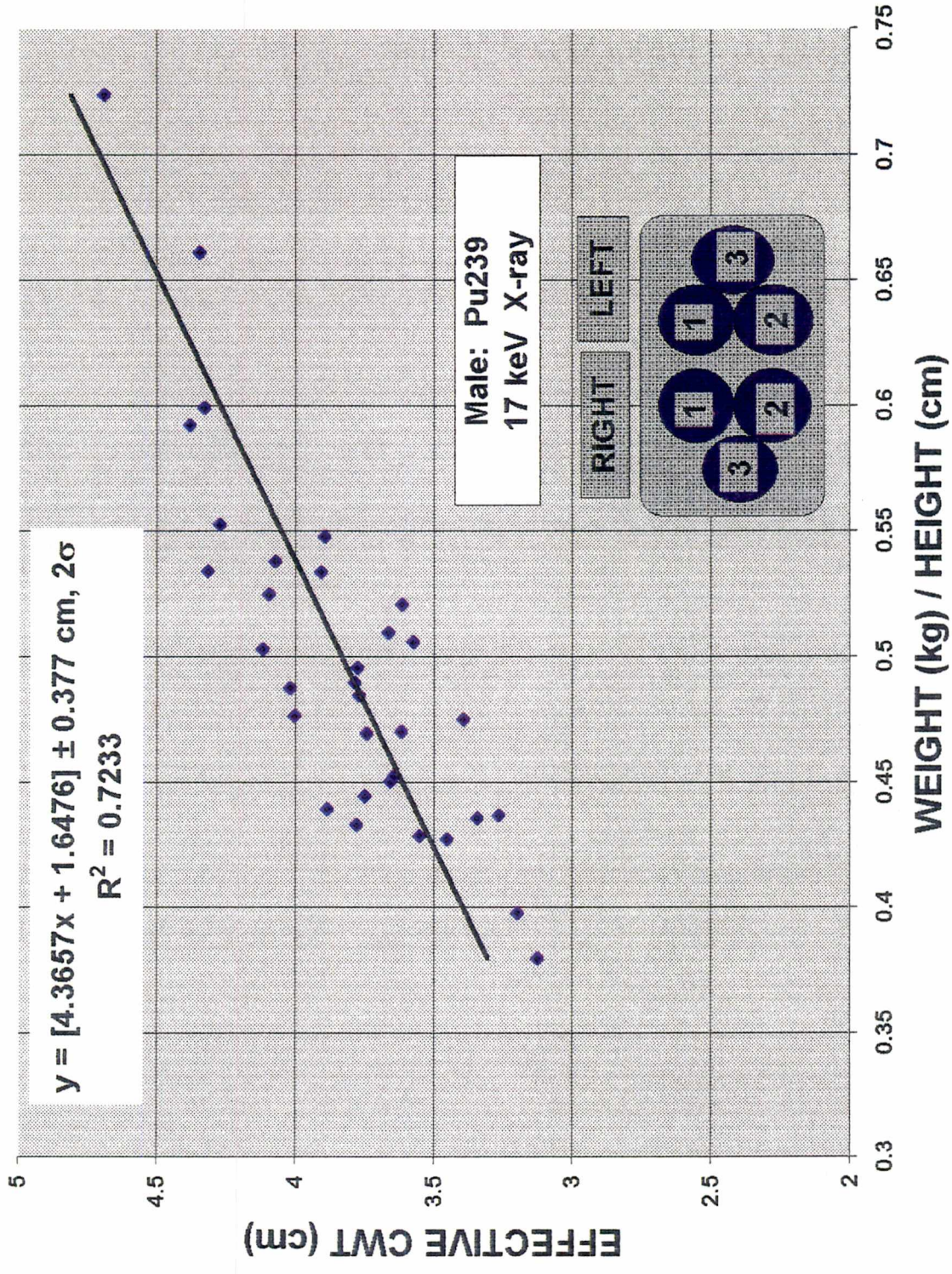



Figure 6-1. Male Total CWT vs. W/H
Average CWT = 3.82 cm

confidence level of the estimate would be $\pm$ 0.383 cm and $R^2$ = 0.7233. If the correlation was used to predict chest wall thicknesses, the largest error would have been + 0.33 cm in an individual whose measured chest wall thickness was 4.32 cm and predicted CWT was 3.99 cm. The predicted value would have overestimated the detector efficiency calibration, and underestimated the activity (nCi) reported within the lungs. Table 6-1 depicts common measurement parameters for 33 subjects.

Table 6-1. Male total CWT common measurement parameters for 33 subjects.

| Parameter | Mean | Minimum | Maximum |
|---|---|---|---|
| Arith Avg CWT, cm | 3.20 | 2.56 | 4.46 |
| Eff Avg CWT, cm | 3.82 | 3.12 | 4.69 |
| Relative Adiposity* | 0.34 | 0.23 | 0.53 |
| Weight, kg (lb) | 87(193) | 61(135) | 129(285) |
| Height, cm (in) | 180(71) | 161(64) | 193(76) |
| Age, y | 43 | 25 | 72 |
| Arith. avg Left Muscle thickness, cm | 2.50 | 1.80 | 3.13 |
| Arith. avg Right Muscle thickness, cm | 2.59 | 1.89 | 3.38 |
| Adult Reference Male Weight, kg (lb) | 70(154) | - | - |
| Adult Reference Male Height, cm (in) | 170(67) | - | - |
| Adult Reference Male Age, y | 20-30 | - | - |

*Arithmetic avg adipose thickness divided by arithmetic avg total thickness of chest wall.
- not applicable.

Presently, there is not a gender-specific CWT prediction equation derived using HPGe detectors. The CWT prediction equations used to compare with the proposed CWT

prediction equation (Vi94) were the only applicable published CWT prediction equations, derived for male subjects positioned supine for the typical, phoswich two-detector system using weight (kg) and height (cm).

The CWT prediction equations used for comparison were the following:

$$\text{CWT (cm)} = 11.05(W/H) - 2.0038 \qquad \text{(An83)} \qquad (6\text{-}10)$$

$$\text{CWT (cm)} = 6.0(W/H) - 0.11 \qquad \text{(Fr80)} \qquad (6\text{-}11)$$

$$\text{CWT (cm)} = 5.12(W/H) + 0.0071 \qquad \text{(De73)} \qquad (6\text{-}12)$$

The An83 CWT equation is the CWT equation in use by the ORNL WBCL and K-25 Site Lung Counter facility, and by most U.S. Department of Energy lung counting facilities which employ the lung counting software supplied by Canberra/Nuclear Data of Itasca, Illinois (Ca89). Table 6-2 compares some of the measurement technique parameters used for each CWT equation.

Table 6-2. Comparison of measurement technique parameters of male CWT equations.

| Parameter | Vi94 | An83 | Fr80 | De73 |
|---|---|---|---|---|
| Number of subjects | 33 | 33 | 172 | 393 |
| Position | recline | supine | supine | standing |
| Number of measm'ts over each lung | 12 | 6* | 7 | 6 |
| $\mu$, $cm^{-1}$ | 0.920 | 0.946* | 0.99 | 1.15 |
| $R^2$ | 0.7233 | 0.9* | 0.750 | 0.806 |
| $2\sigma$, cm $\pm$ | 0.383 | 0.642 | 0.54 | 0.40 |
| Mean Eff CWT, cm | 3.82 | 2.8* | 2.48 | 2.26 |

*exact value unavailable; the An83 CWT equation has not been formally published.

Figure 6-2 shows the comparison of the male total CWT prediction (Vi94) line compared to several published phoswich CWT prediction lines.

Considering the average CWT (Vi94) of 3.82 cm corresponding to a weight/height ratio of 0.5 kg/cm, the CWT equations used for comparison would predict the following relative percent errors to the predicted total CWT equation (Vi94) as shown in Table 6-3.

Table 6-3. Relative percent error between the male total CWT (Vi94) and several published CWT values at W/H = 0.5 kg/cm.

| Prediction CWT Eqn | % Error |
|---|---|
| An83 | - 8% |
| Fr80 | - 25% |
| De73 | - 33% |

The two-detector array is employed by the K-25 Site Lung Counter facility. The array describes the L1 and R1 detector positions. The male effective CWT prediction equation for the two-detector array is given by

$$\text{CWT (cm)} = 3.9939(\text{W/H}) + 1.1558 \quad \text{(Vi94)}. \tag{6-13}$$

Figure 6-3 is a plot of the individual CWT results against the CWT prediction line as function of the ratio of weight/height. The mean effective CWT was 3.14 cm with a $2\sigma$ standard deviation of $\pm$ 0.340 cm and $R^2 = 0.7285$. The standard deviation, $1\sigma$, of the individual measurements was $\pm$ 0.34 cm; individual results varied in range from 2.57 to 4.05 cm. The mean arithmetic CWT was 2.83 cm for a tissue composition (by thickness) of 34% adipose and 66% muscle. If the proposed correlation (Vi94) was used to predict chest wall thicknesses, the largest error would have been - 0.35 cm in an individual whose measured

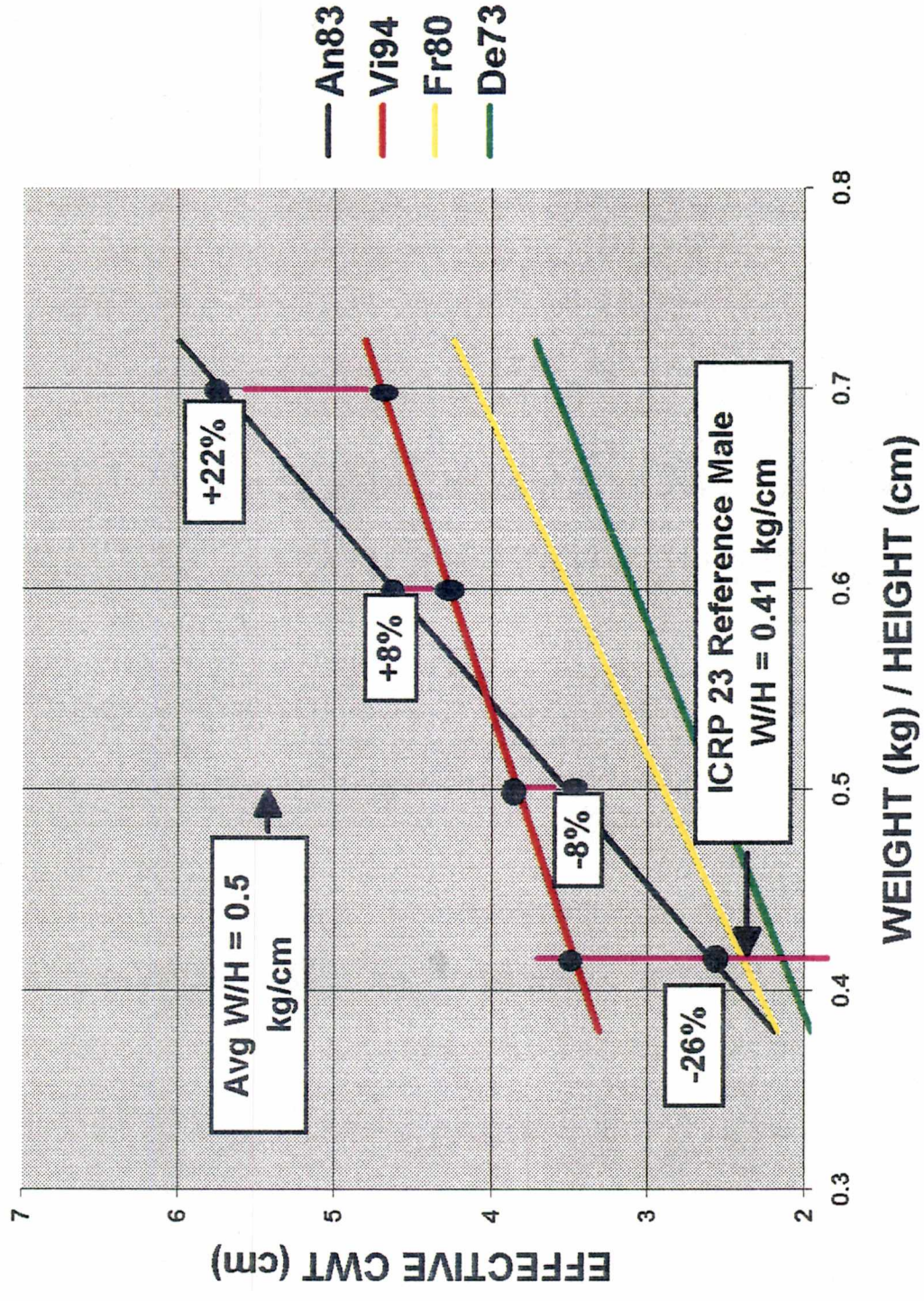



Figure 6-2. Comparison of the Male Total CWT Equation Vi94 with Several Published Prediction Equations and the Relative Percent Errors in CWT of the An83 Equation

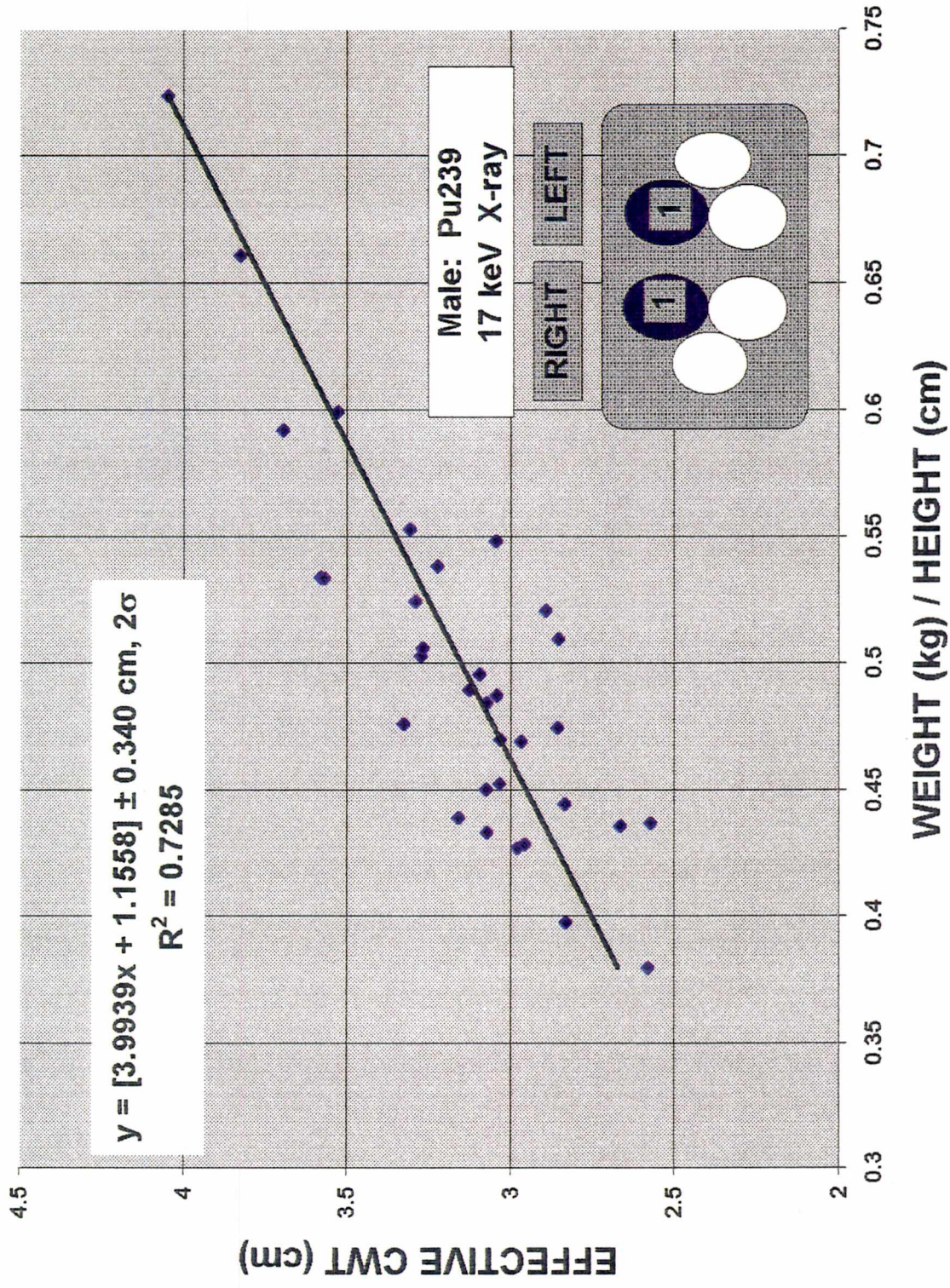



Figure 6-3. Male L1/R1 CWT vs. W/H
Average CWT = 3.14 cm

chest wall thickness was 2.89 cm and predicted CWT was 3.24 cm. The predicted value would have underestimated the detector efficiency, and overestimated the activity (nCi) reported. The percent error in the efficiency calibration would have been - 31%. Figure 6-4 shows the relative percent error in efficiency calibration of the two-detector HPGe array male CWT equation (Vi94) to the present CWT equation (An83) which was derived using the phoswich two-detector array.

The three-detector array is employed by the ORNL WBCL and describes the L1, R1 and R2 detector positions. The male effective CWT prediction equation for the three-detector array is given by

$$\text{CWT (cm)} = 4.3379(\text{W/H}) + 1.2513 \quad \text{(Vi94)}. \tag{6-14}$$

Figure 6-5 is a plot of the individual CWT results against the CWT prediction equation as a function of the ratio of weight/height. The mean effective CWT was 3.41 cm with a $1\sigma$-standard deviation of $\pm$ 0.36 cm; individual results varied in range from 2.78 to 4.29 cm. The mean arithmetic CWT was 3.20 cm for a tissue composition (by thickness) of 34% adipose and 66% muscle. In the absence of an ultrasonic measurement of chest wall thickness, this equation would be used to predict a value of the CWT. The standard error at the 95% confidence level of the estimate would be $\pm$ 0.350 cm and $R^2 = 0.7502$. If the proposed correlation was used to predict chest wall thicknesses, the largest error would have been - 0.36 cm in an individual whose measured chest wall thickness was 2.79 cm and predicted CWT was 3.15 cm. The predicted CWT would have underestimated the detector efficiency calibration, and overestimated the activity (nCi) reported. The percent error in efficiency calibration would have been - 32%. Figure 6-6 shows the relative percent error in detector efficiency calibration of the three-detector HPGe array male CWT equation (Vi94) to the present CWT equation (An83) which was derived using the phoswich two-detector

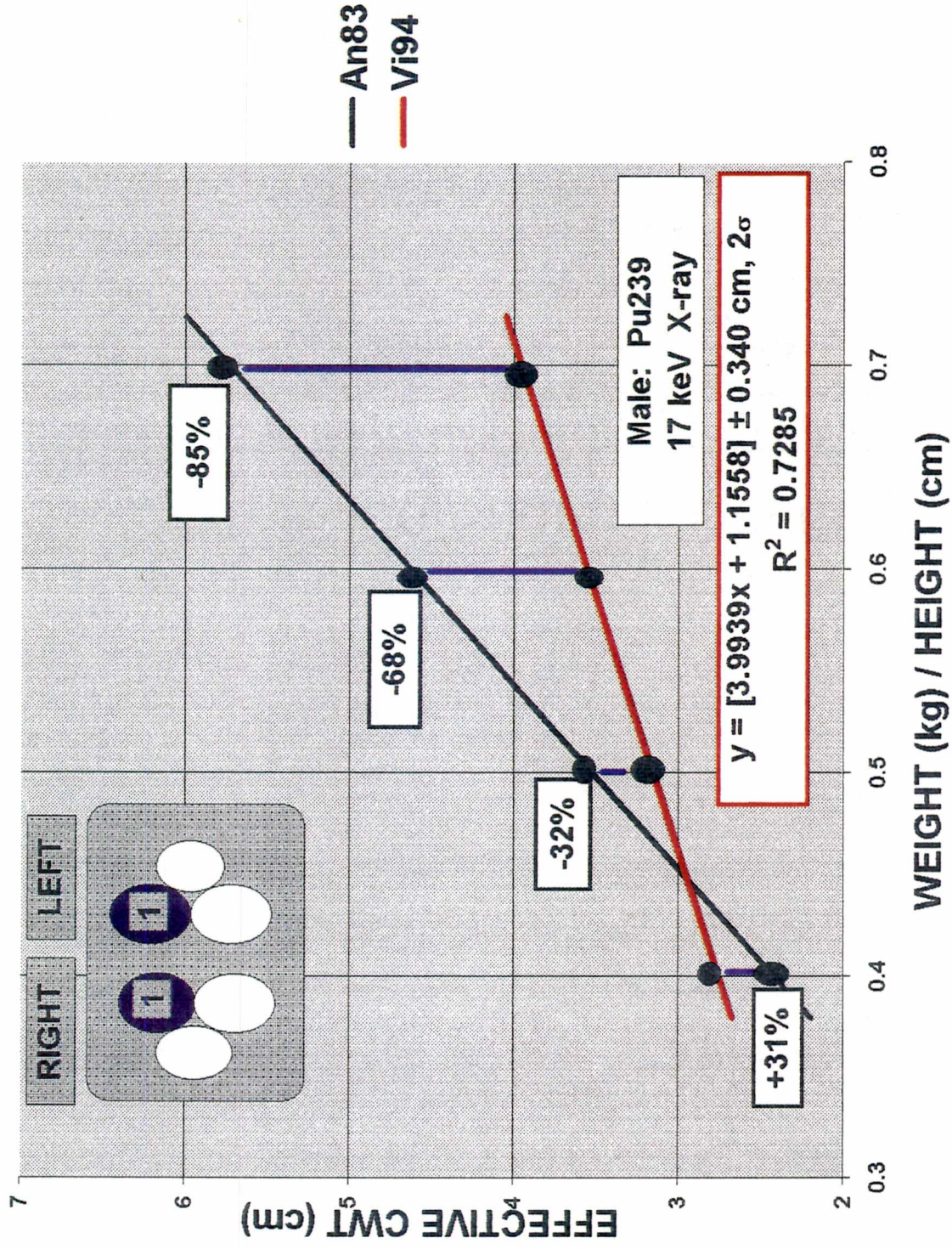



Figure 6-4. Relative Percent Errors in Detection Efficiency Using the Current CWT Equation An83 versus the Male CWT Equation Vi94 Two Detector Array

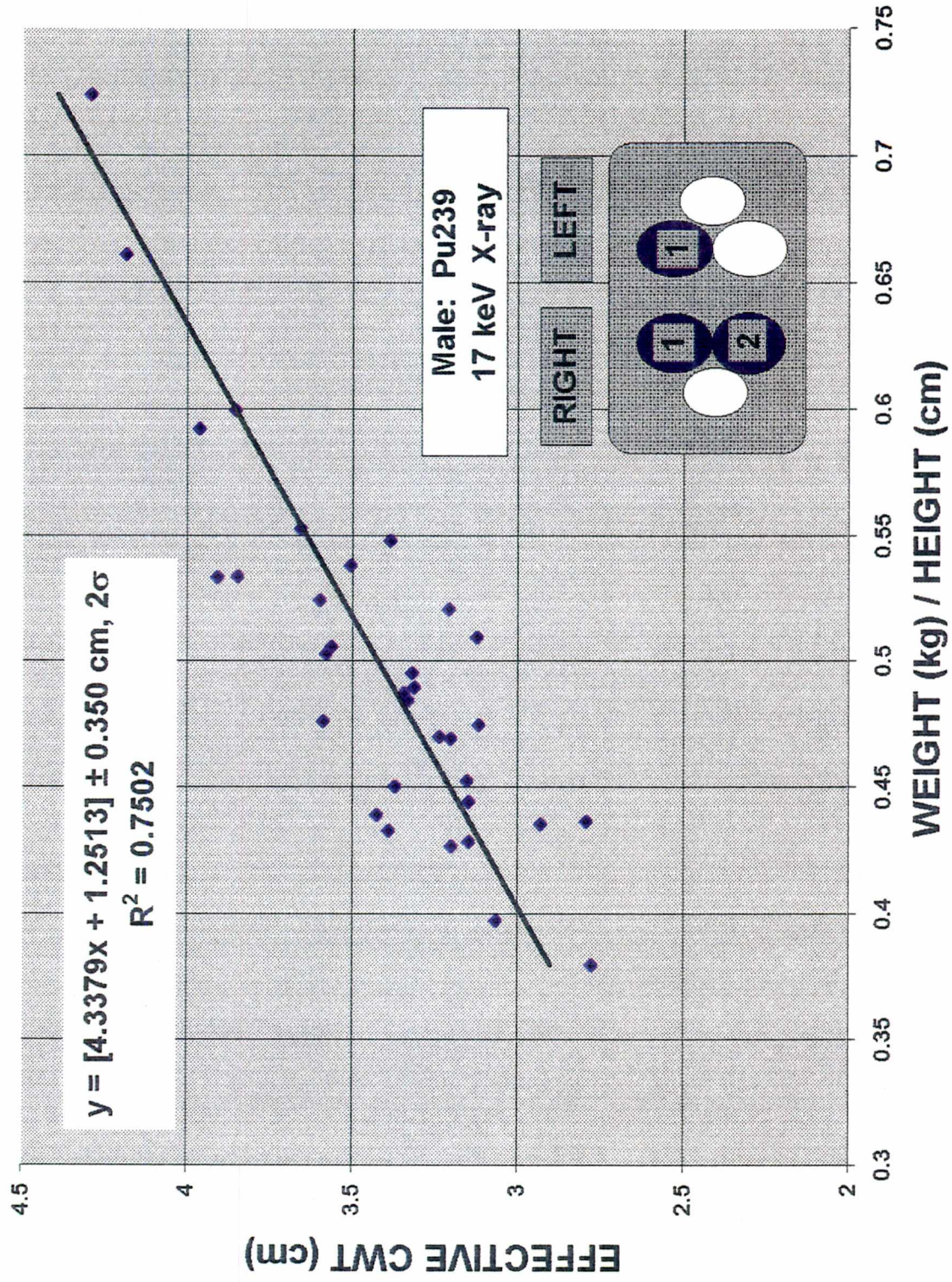



Figure 6-5. Male L1/R1/R2 CWT vs. W/H
Average CWT = 3.41 cm

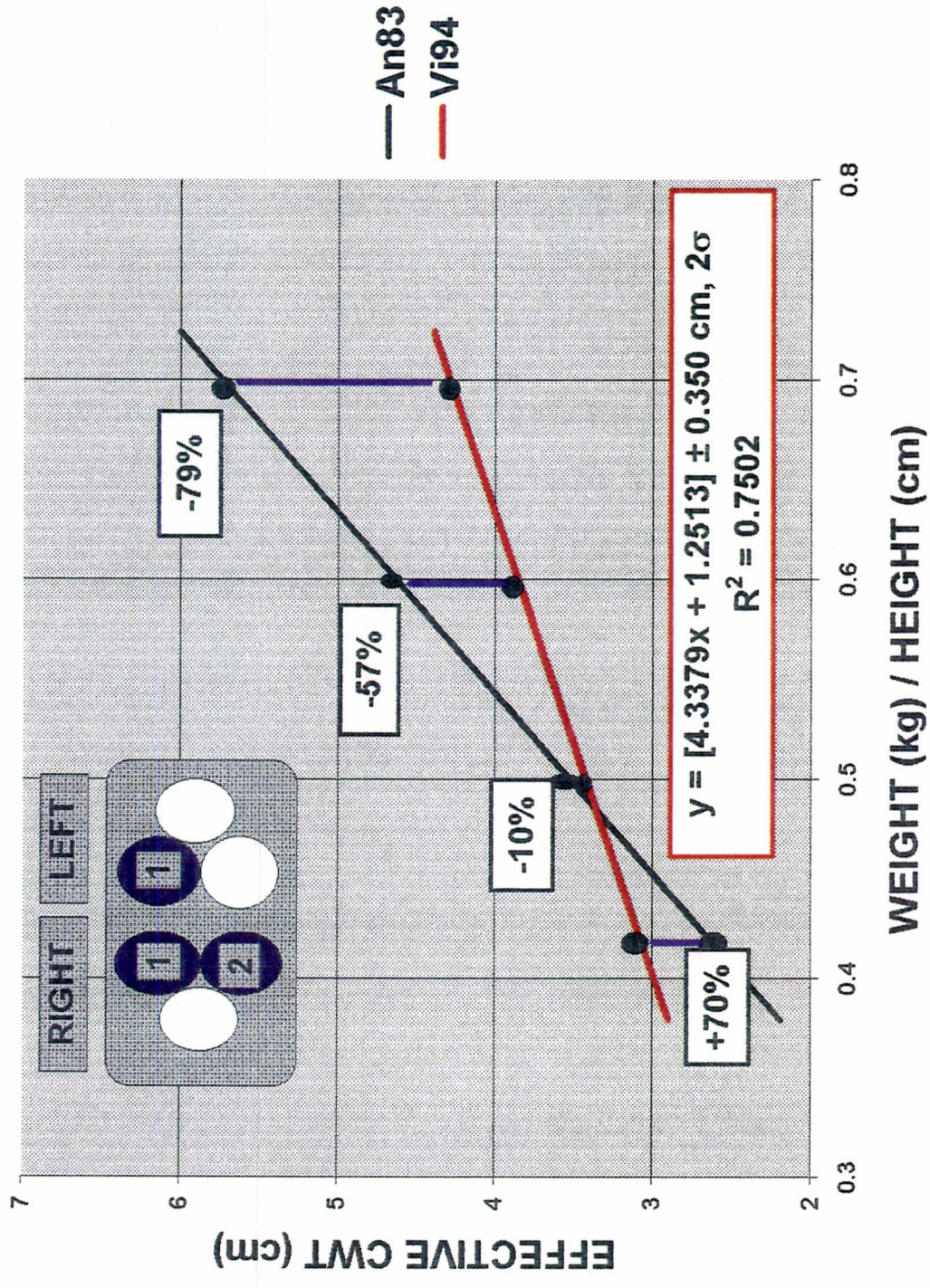



Figure 6-6. Relative Percent Errors in Detection Efficiency Using the Current CWT Equation An83 versus the Male CWT Equation Vi94 Three-Detector Array

array. Figure 6-7 shows the summary of the $^{239}$Pu CWT prediction equations for the two-, three- and six-detector HPGe arrays compared to the An83, Fr80 and De73 CWT prediction equations. Figure 6-8 shows the male total thickness (mm) data of this research used in the same equation as used by Fr80 and De73 for computing the six-detector effective CWT with $\mu$ = 0.99 cm$^{-1}$ thus, enabling the most comparable analysis possible, and any difference is presumed to be attributed to the measurement locations for the total CWT which is different for the HPGe six-detector array compared to the two-detector phoswich arrays used by Fr80 and De73, furthermore, the exact ultrasonic measurement locations of Fr80 and De73 are not known.

The following results derived for $^{241}$Am 59.5 keV photons and the male total CWT relate to measurements using a standard technique for all 33 subjects. The mean effective CWT was 3.82 cm with a 1$\sigma$-standard deviation of $\pm$ 0.48 cm; individual results varied in range from 3.12 to 5.13 cm. Linear regression analysis indicated the data could be represented by the function

$$\text{CWT (cm)} = 5.5778(\text{W/H}) + 1.0458 \quad \text{(Vi94)}. \tag{6-15}$$

This predicted CWT line is shown in Figure 6-9. In the absence of an ultrasonic measurement of chest wall thickness, this equation could be used to predict a value of CWT. The standard error at the 95% confidence level of the estimate would be $\pm$ 0.537 cm and $R^2$ = 0.6776. If the correlation was used to predict chest wall thicknesses, the largest error would have been + 0.95 cm in an individual whose measured chest wall thickness was 4.72 cm and predicted CWT was 3.76 cm. The predicted value would have overestimated the detector efficiency calibration, and underestimated the activity (nCi) reported within the lungs. The male total CWT for $^{241}$Am 59.5 keV photons was compared only to the An83 phoswich derived CWT prediction equation.

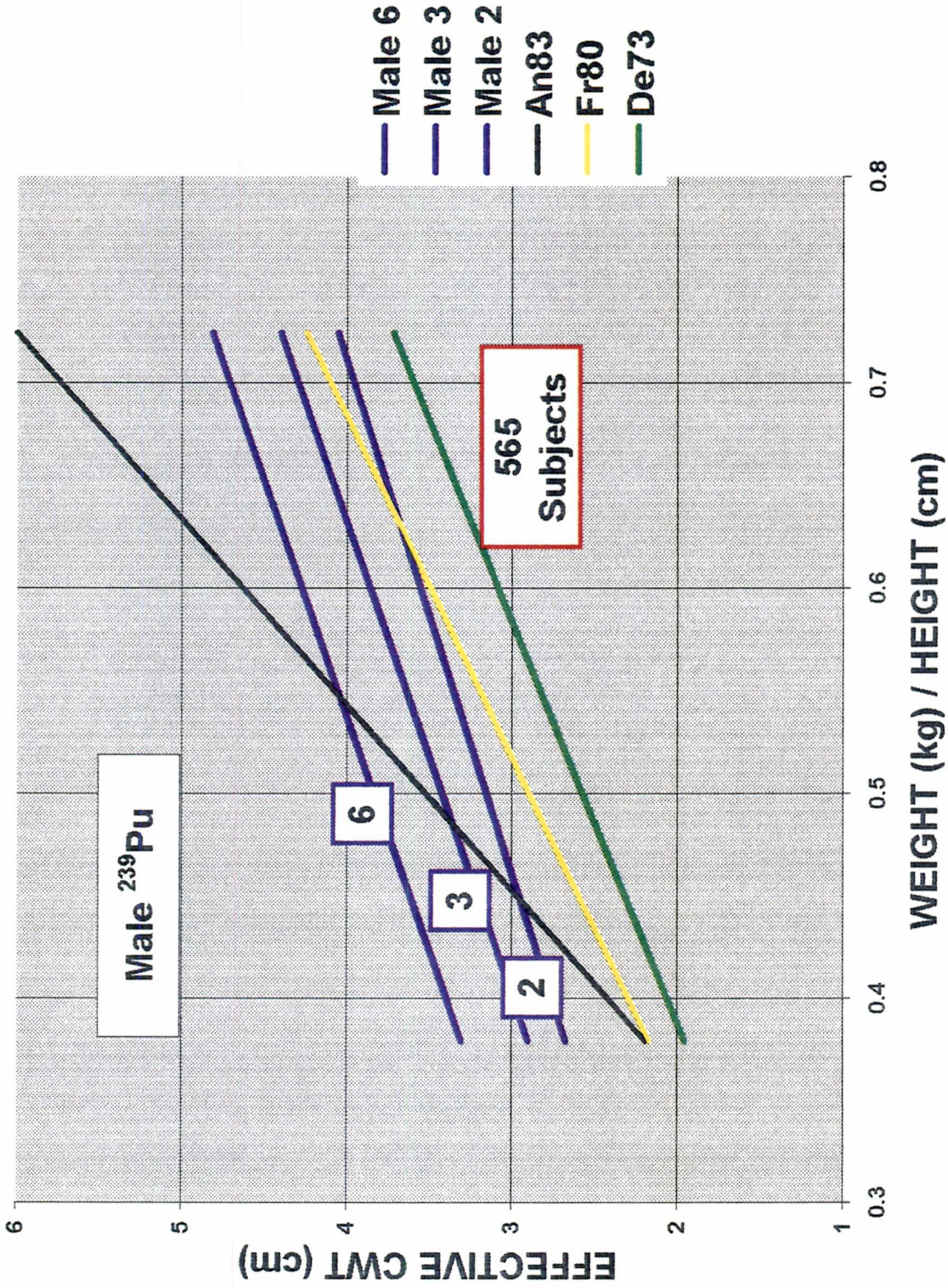



Figure 6-7. Summary of the Male $^{239}Pu$ CWT Prediction Equations

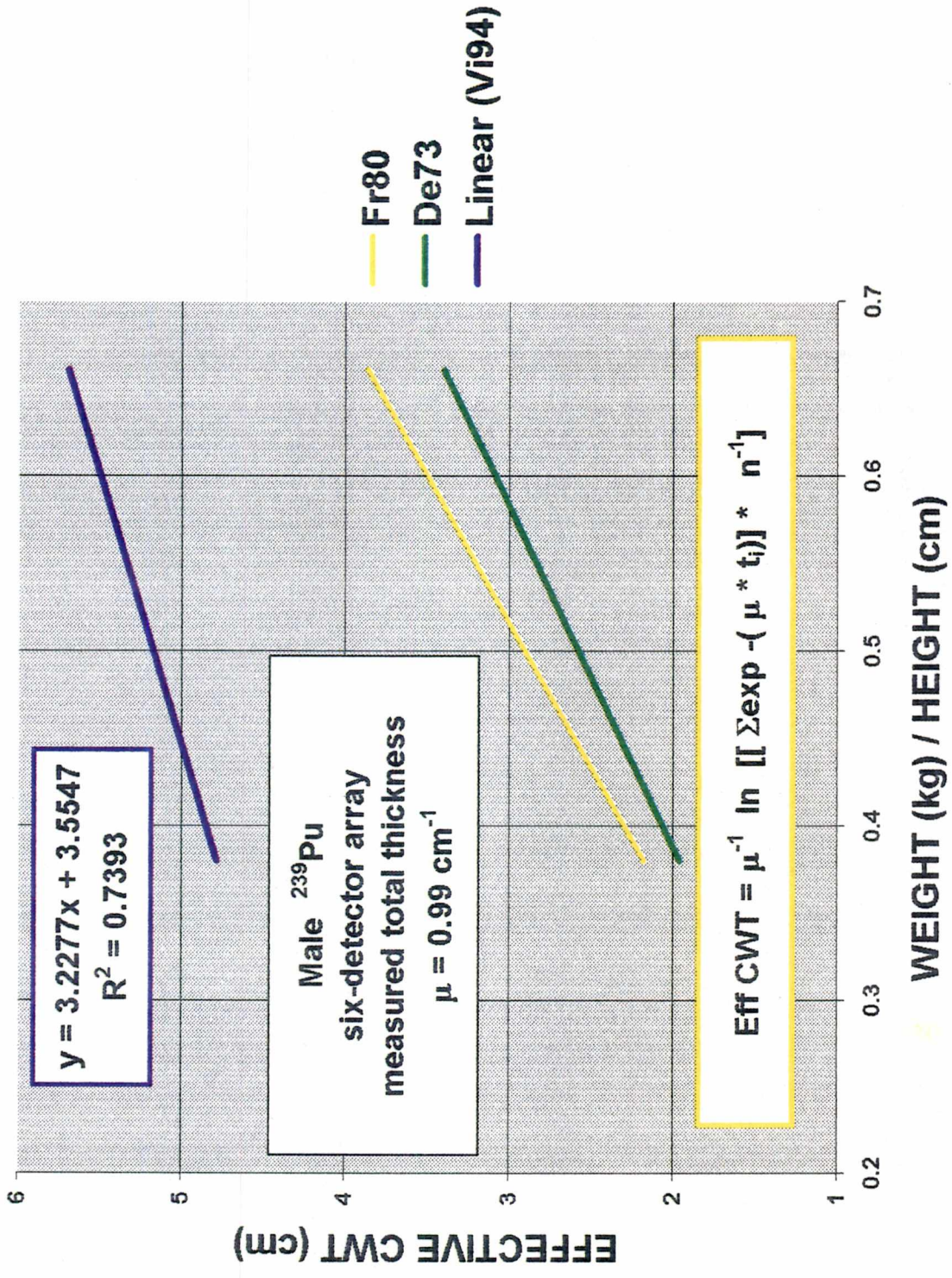



Figure 6-8. Six-Detector Array Male $^{239}$Pu CWT Comparison with Fr80 and De73

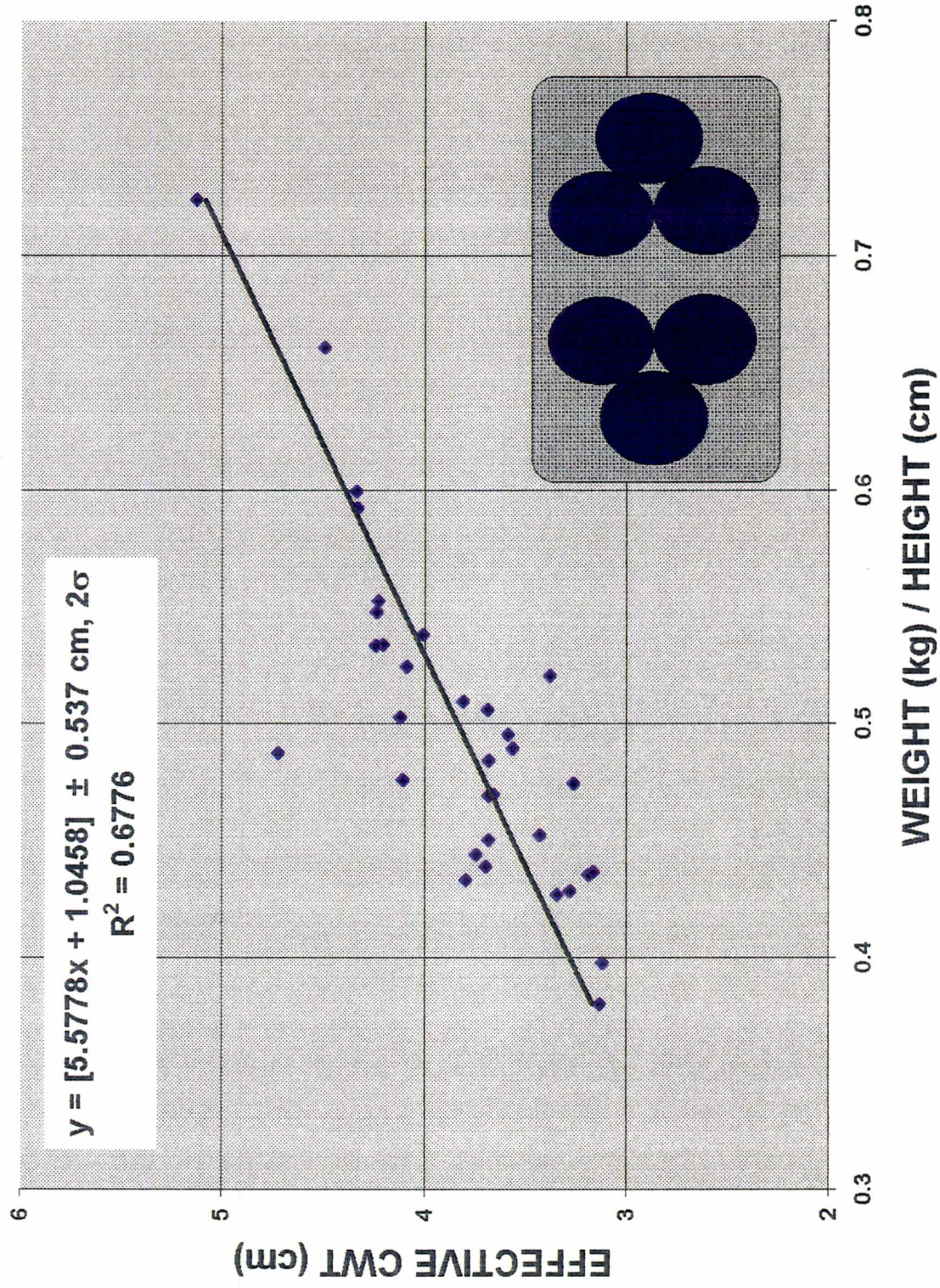



Figure 6-9. Male Total CWT for $^{241}Am$
Average CWT = 3.82 cm

Table 6-4 compares some of the measurement technique parameters used for each CWT equation.

Table 6-4. Comparison of male $^{241}Am$ measurement technique parameters with An83 CWT equation.

| Parameter | Vi94 | An83 |
|---|---|---|
| Number of subjects | 33 | 33 |
| Position | recline | supine |
| No. of measm'ts/lung | 12 | 6* |
| $\mu$, $cm^{-1}$ | 0.184 | 0.946* |
| $R^2$ | 0.6776 | 0.9* |
| $2\sigma$, $cm^{-1}$ | 0.537 | 0.642 |
| Mean Eff CWT, cm | 3.82 | 2.8* |

*exact value unavailable; the An83 CWT equation has not been formally published.

The two-detector array describes the L1 and R1 detector positions and the associated derived male CWT prediction equation is given by

$$\text{CWT (cm)} = 4.1896(W/H) + 0.8167\ (Vi94). \qquad (6\text{-}16)$$

Figure 6-10 is a plot of the individual CWT results against the CWT prediction line as function of weight/height (kg/cm). The mean effective CWT was 2.90 cm with a $2\sigma$-standard deviation of $\pm$ 0.359 cm and $R^2$ = 0.7262. The standard deviation, $1\sigma$, of the individual measurements was $\pm$ 0.35 cm; individual results varied in range from 2.39 to 4.02 cm. If the proposed correlation had been used to predict chest wall thicknesses, the largest error would have been - 0.43 cm in an individual whose measured CWT was 2.56 cm and predicted CWT was 2.99 cm. The predicted CWT value would have underestimated the efficiency calibration and overestimated the activity (nCi) reported within the lungs. The percent error in efficiency calibration would have been - 16%.

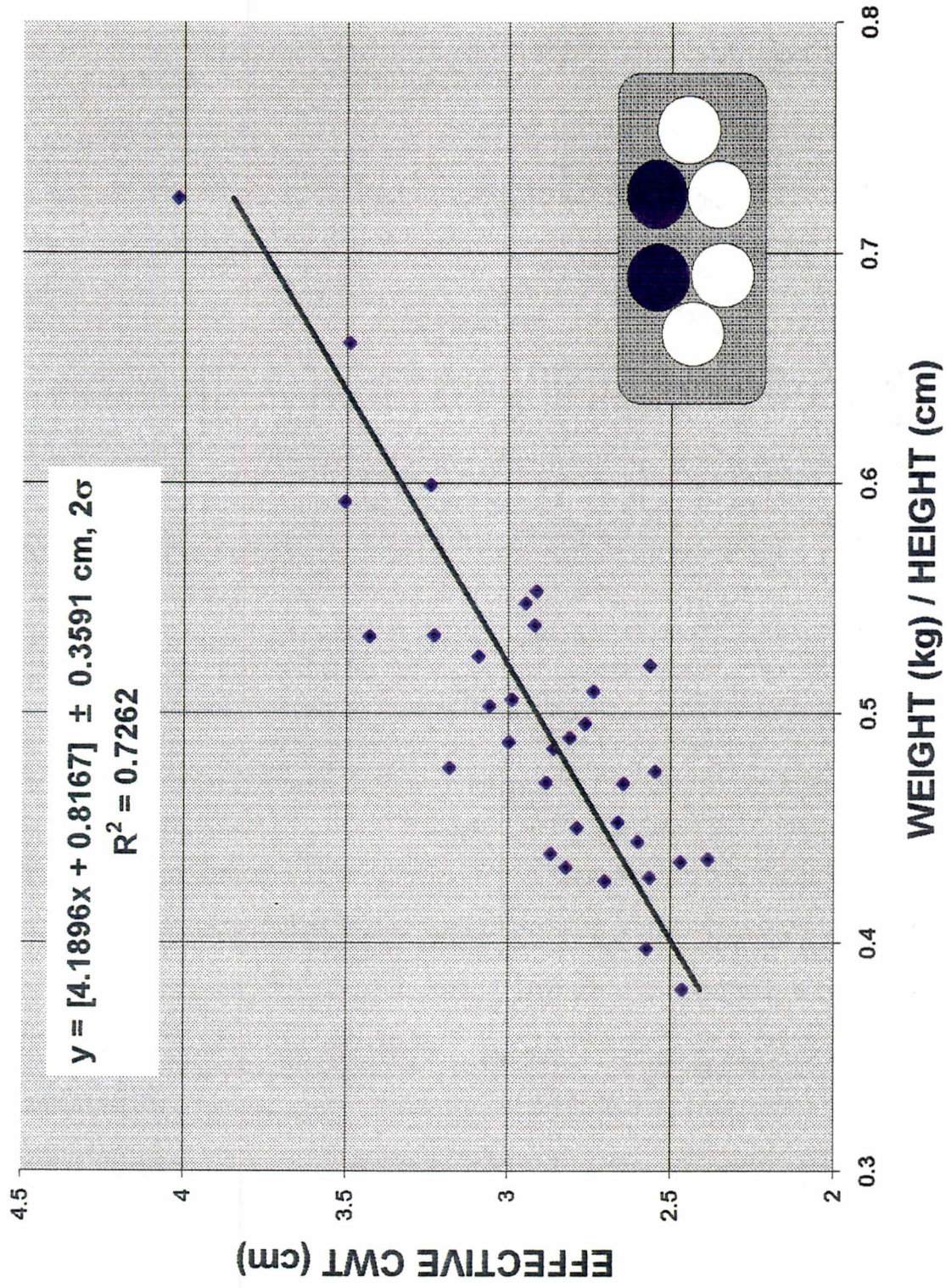



Figure 6-10. Male L1/R1 CWT vs. W/H for $^{241}Am$
Average CWT = 2.90 cm

The three-detector array describes the L1, R1 and R2 detector positions and the associated derived male CWT prediction equation is given by

$$\text{CWT (cm)} = 4.8103(W/H) + 0.8492\ (Vi94). \qquad (6\text{-}17)$$

Figure 6-11 is a plot of the individual CWT results against the CWT prediction line as a function of the ratio of weight/height (kg/cm). The mean effective CWT was 3.24 cm with a $1\sigma$-standard deviation of $\pm$ 0.404 cm; individual results varied in range from 2.61 to 4.41 cm. In the absence of an ultrasonic measurement of chest wall thickness, this equation would be used to predict a value of CWT. The standard error at the 95% confidence level of the estimate would be $\pm$ 0.421 cm and $R^2 = 0.718$. If the proposed correlation were used to predict chest wall thicknesses, the largest error would have been + 0.494 cm in an individual whose measured CWT was 3.91 cm and predicted CWT was 3.42 cm. The predicted CWT would have overestimated the efficiency calibration and underestimated the activity reported (nCi) within the lungs. The percent error in efficiency calibration would have been +19 %. Figure 6-12 shows the summary of the $^{241}Am$ male CWT prediction equations for the two-, three- and six-detector HPGe arrays compared to the An83 CWT prediction equation.

The mean arithmetic male CWT increases by 70% laterally from the R1 to R3 detector positions, and by 30% transversely from the R1 to R2 detector positions. Figure 6-13 shows the increase in CWT laterally and transversely as a plot of the CWTs for each detector position which as a sum encompasses the total chest area measured.

## Female Data Analysis

The following results derived for $^{239}Pu$ and the female total CWT relate to measurements using a standard technique for all 37 subjects. Using linear regression analysis, the data could be represented by the function

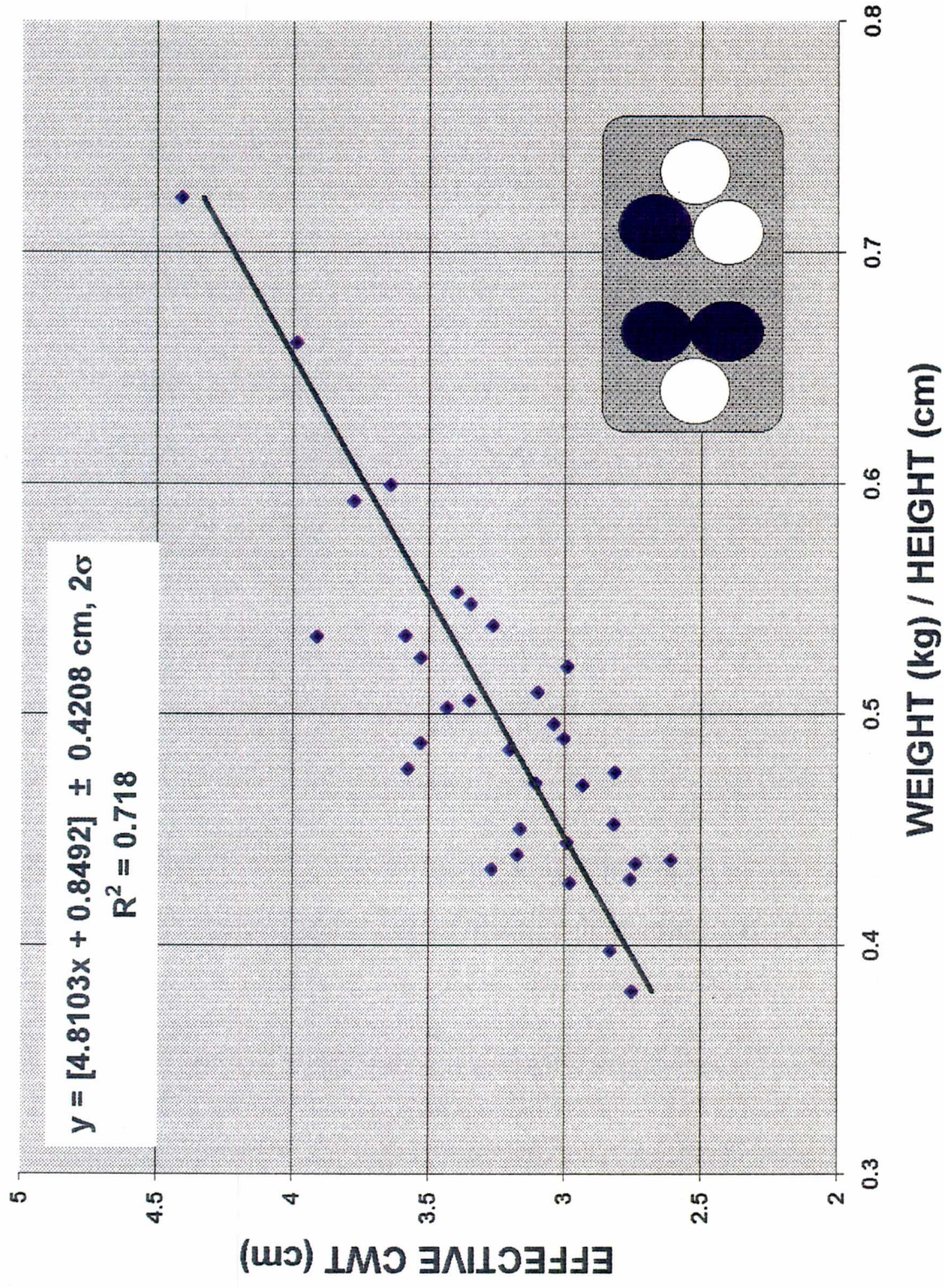



Figure 6-11. Male L1/R1/R2 CWT vs. W/H for $^{241}Am$
Average CWT = 3.24 cm

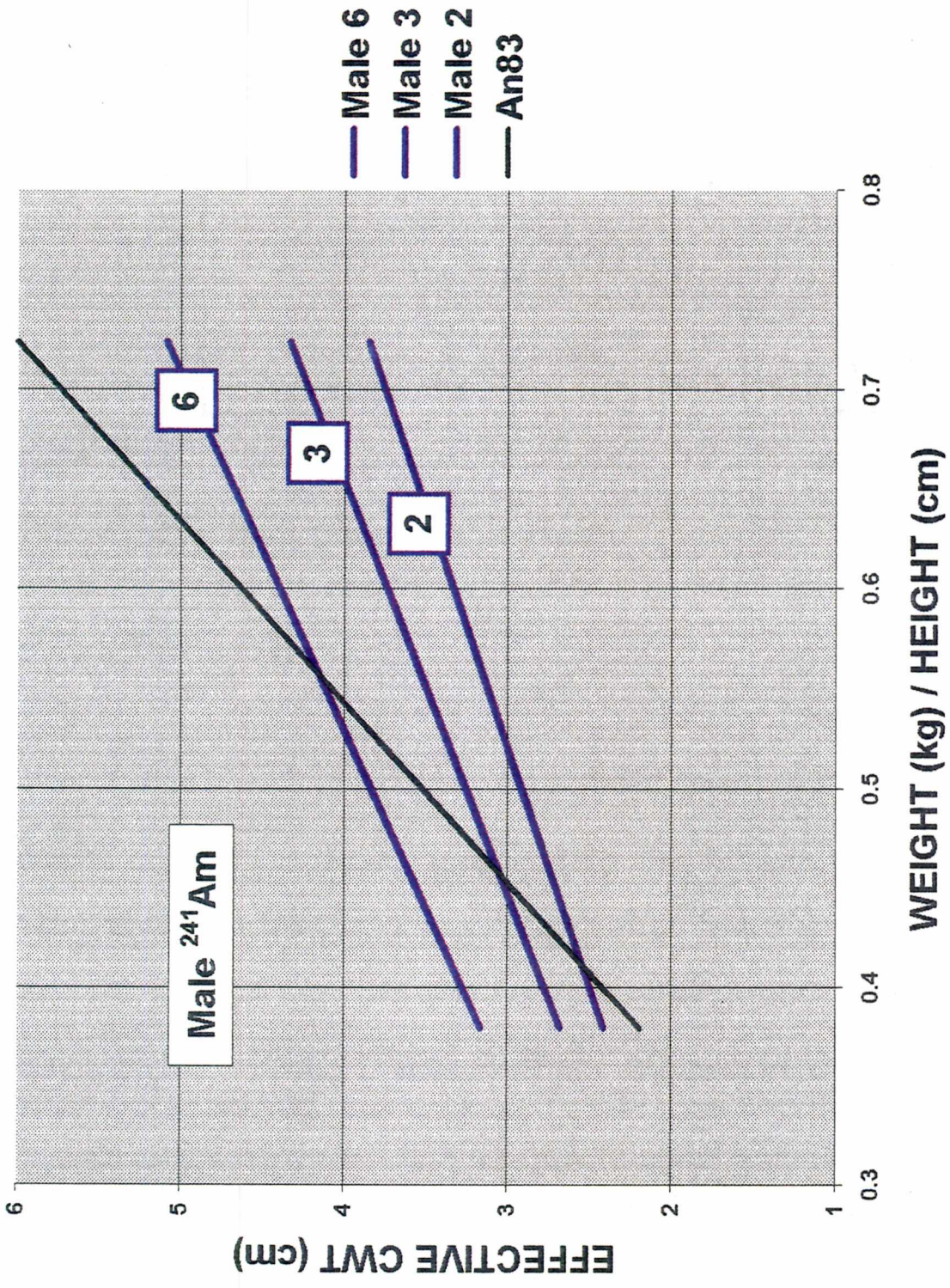



Figure 6-12. Summary of the Male $^{241}$Am CWT Prediction Equations

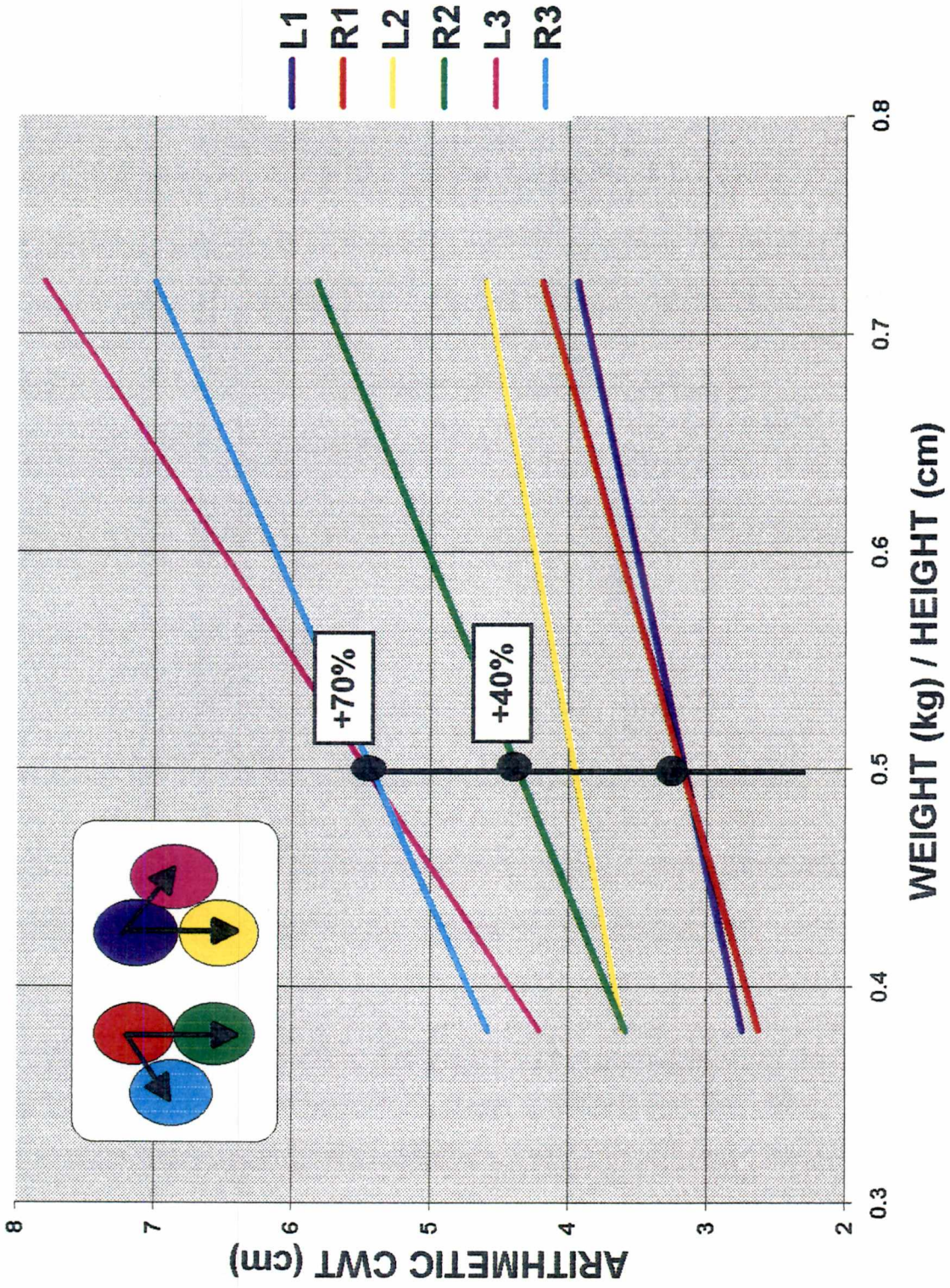



Figure 6-13. Male Arithmetic CWT Increases by 70% Laterally (R1 to R3) and by 40% Transversely (R1 to R2)

$$\text{CWT (cm)} = 6.3727(\text{W/H}) + 0.4283 \quad \text{(Vi94)}. \tag{6-18}$$

The individual results are plotted in Figure 6-14 as a function of the ratio of weight/height. The mean effective chest wall thickness was 2.95 cm with a $1\sigma$-standard deviation of $\pm$ 0.54 cm; individual results varied in range from 1.76 to 4.35 cm. The mean arithmetic CWT was 3.69 cm for a measured total tissue composition of 64% adipose and 36% muscle. The effective CWT is a smaller estimate than the arithmetic CWT most probably due to the increase in adipose thickness (twice the thickness of muscle). Adipose tissue attenuates low energy photons less than muscle by a factor of two, therefore, the photon flux is much less attenuated and a smaller effective CWT value is calculated; the same applies for the analysis of the arithmetic CWT versus effective CWT for the two- and three-detector array configurations. The female chest area measured is of unique anatomical structure due to variations in adipose (breast) tissue thickness. The adipose thicknesses significantly varied in the measured regions of interest among the female subjects. The L1 and R1 detectors are positioned on the upper thorax which do not encompass the adipose tissue. Consequently, the L1 and R1 detector positions are the most comparable of female subjects, and the associated derived CWT prediction equation is the one selected of the three detector configurations for routine lung counting measurements. Furthermore, the tissue composition of adipose and muscle is unique for each detector configuration because of the different measured regions of interest consisting of variable adipose thicknesses. In the absence of an ultrasonic measurement of chest wall thickness, this relationship would be used to predict a value of CWT. The standard error at the 95% confidence level of the estimate would be $\pm$ 0.507 cm and $R^2$ = 0.7688. If the proposed correlation was used to predict chest wall thicknesses, the largest error would have been + 0.53 cm in an individual whose measured chest wall thickness was 3.90 cm and predicted CWT was 3.36 cm. The predicted value would

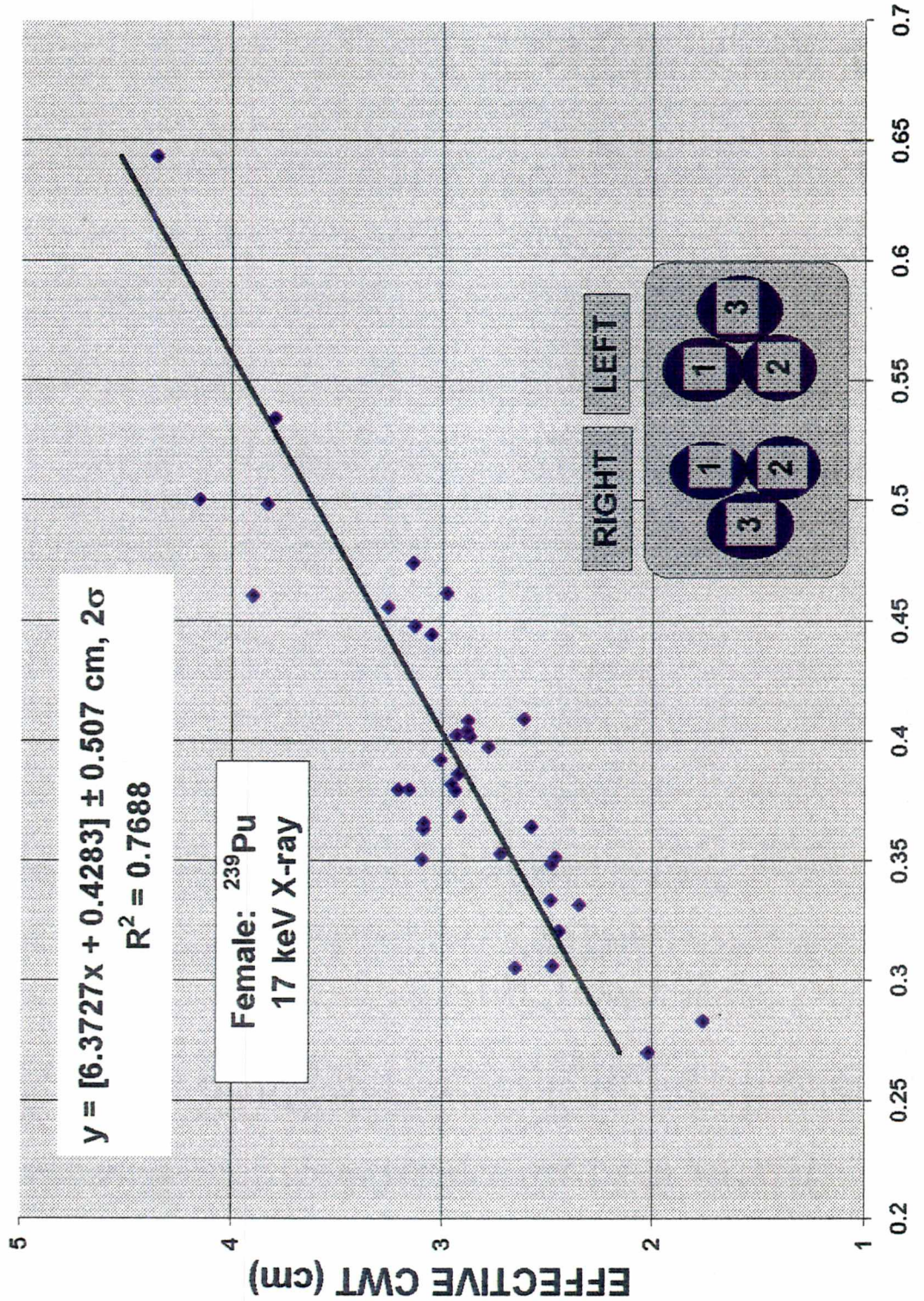



Figure 6-14. Female Total CWT vs. W/H
Average CWT = 2.95 cm

have overestimated the detector efficiency, and underestimated the activity (nCi) reported. Table 6-5 depicts common measurement parameters for 37 subjects.

Table 6-5. Female total CWT common measurement parameters for 37 subjects.

| Parameter | Mean | Minimum | Maximum |
|---|---|---|---|
| Arith Avg CWT, cm | 3.69 | 2.11 | 5.61 |
| Eff Avg CWT, cm | 2.95 | 1.76 | 4.35 |
| Relative Adiposity* | 0.64 | 0.44 | 0.76 |
| Weight, kg (lb) | 65(144) | 40(87) | 99(219) |
| Height, cm (in) | 165(65) | 145(57) | 175(69) |
| Age, y | 39 | 24 | 61 |
| Arith avg Left Muscle thickness, cm | 1.31 | 0.73 | 2.36 |
| Arith avg Right Muscle thickness, cm | 1.31 | 0.69 | 2.50 |
| Adult Reference Female Weight, kg (lb) | 58(128) | - | - |
| Adult Reference Female Height, cm (in) | 160(63) | - | - |
| Adult Reference Female Age, y | 20-30 | - | - |

*Arithmetic avg adipose thickness divided by arithmetic avg total thickness of chest wall.
- not applicable.

The female total CWT (Vi94) was compared to the phoswich derived CWT prediction equations. Table 6-6 compares some of the measurement technique parameters used for each CWT equation.

Table 6-6. Comparison of female CWT measurement technique parameters with several CWT equations.

| Parameter | Vi94 | An83 | Fr80 | De73 |
|---|---|---|---|---|
| Number of subjects | 37 | 33 | 172 | 393 |
| Position | recline | supine | supine | standing |
| Number of measm'ts over each lung | 12 | 6* | 7 | 6 |
| $\mu$, $cm^{-1}$ | 0.920 | 0.946* | 0.99 | 1.15 |
| $R^2$ | 0.7688 | 0.9* | 0.750 | 0.806 |
| $2\sigma$, cm $\pm$ | 0.507 | 0.642 | 0.54 | 0.40 |
| Mean Eff CWT, cm | 2.95 | 2.8* | 2.48 | 2.26 |

*exact value unavailable; the An83 CWT equation has not been formally published.

Figure 6-15 shows the comparison of the female total CWT prediction line (Vi94) to several published phoswich CWT prediction lines. Considering the average CWT of 2.95 cm corresponding to a weight/height ratio of 0.4 kg/cm, the compared CWT equations would predict the following relative percent errors to our predicted total CWT equation (Vi94) as shown in Table 6-7.

Table 6-7. Relative percent error between the female total CWT (Vi94) and several published CWT values at W/H = 0.4 kg/cm.

| Prediction CWT Eqn | % Error |
|---|---|
| An83 | - 19% |
| Fr80 | - 23% |
| De73 | - 31% |

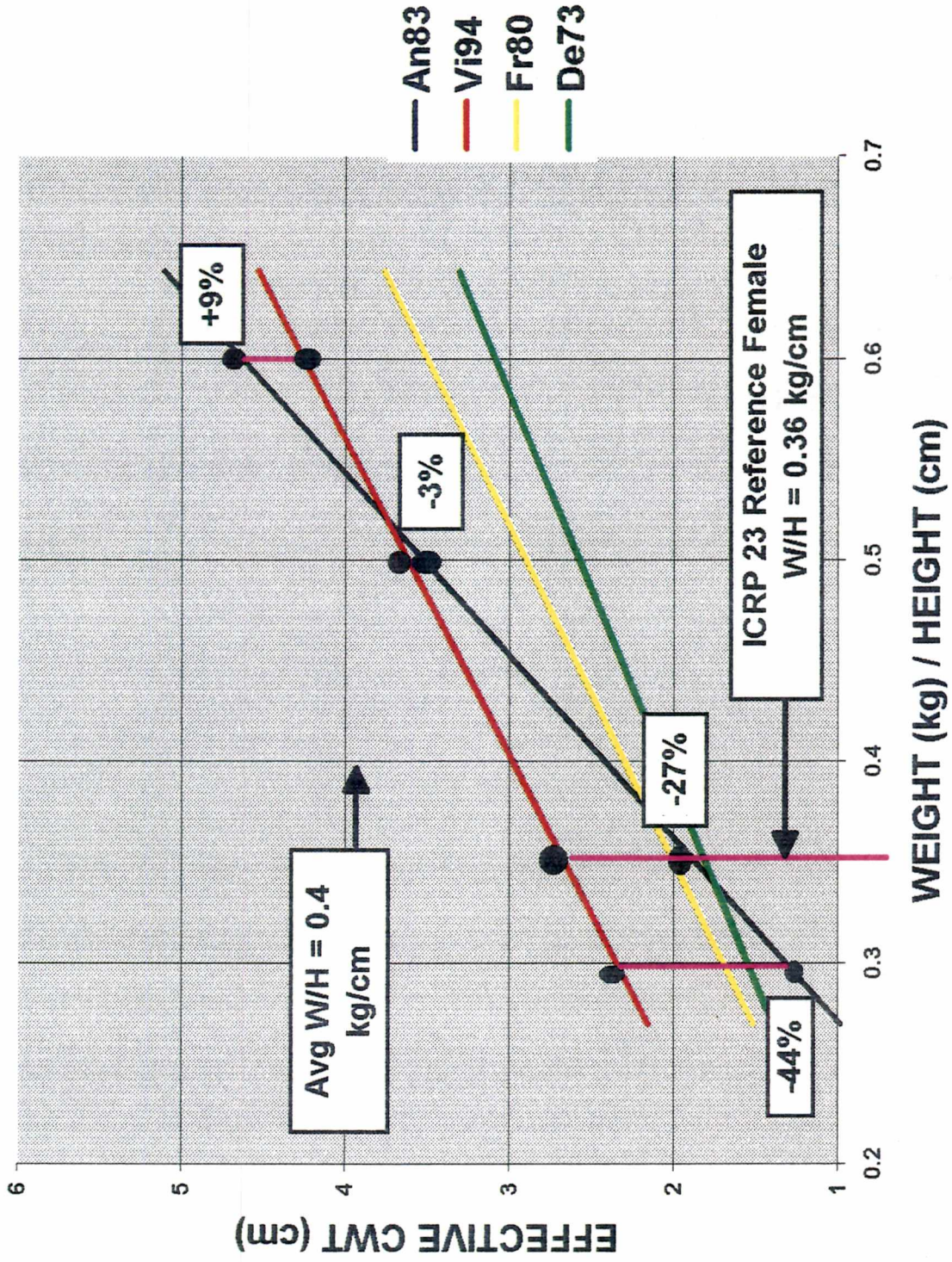



Figure 6-15. Comparison of the Female Total CWT Equation Vi94 with Several Published Prediction Equations and the Relative Percent Errors in CWT of the An83 Equation

The two-detector array describes the L1 and R1 detector positions and the associated derived female CWT prediction equation is given by

$$\text{CWT (cm)} = 5.4506(\text{W/H}) + 0.1353 \quad \text{(Vi94)}. \tag{6-19}$$

Figure 6-16 is a plot of the individual CWT results against the CWT prediction line as a function of the ratio of weight/height. The mean effective CWT was 2.30 cm with a $2\sigma$ standard deviation of $\pm$ 0.496 cm and $R^2 = 0.712$. The $1\sigma$-standard deviation of the individual measurements was $\pm$ 0.48 cm; individual results varied in range from 1.43 to 3.64 cm. The mean arithmetic CWT was 3.06 cm for a tissue composition (by thickness) of 47% adipose and 53% muscle. If the proposed correlation had been used to predict chest wall thicknesses, the largest error would have been + 0.58 cm in an individual whose measured CWT was 3.44 cm and predicted CWT was 2.86 cm. The predicted value would have overestimated the detector efficiency, and underestimated the activity (nCi) reported. The percent error in efficiency calibration would have been + 86%. Figure 6-17 shows the relative percent error in efficiency calibration of the two-detector HPGe female CWT prediction equation (Vi94) to the present CWT prediction equation (An83) which was derived using the phoswich two-detector array.

The three-detector array describes the L1, R1 and R2 detector positions and the associated derived female CWT prediction equation is given by

$$\text{CWT (cm)} = 5.6026(\text{W/H}) + 0.3541 \quad \text{(Vi94)}. \tag{6-20}$$

Figure 6-18 is a plot of the individual CWT results against the CWT prediction line as a function of the ratio of weight/height. The mean effective CWT was 2.57 cm with a $1\sigma$-standard deviation of $\pm$ 0.48 cm; individual results varied in range from 1.50 to 3.78 cm. The mean arithmetic CWT was 3.51 cm for a tissue composition (by thickness) of 58% adipose and 42% muscle. In the absence of an ultrasonic measurement of chest wall

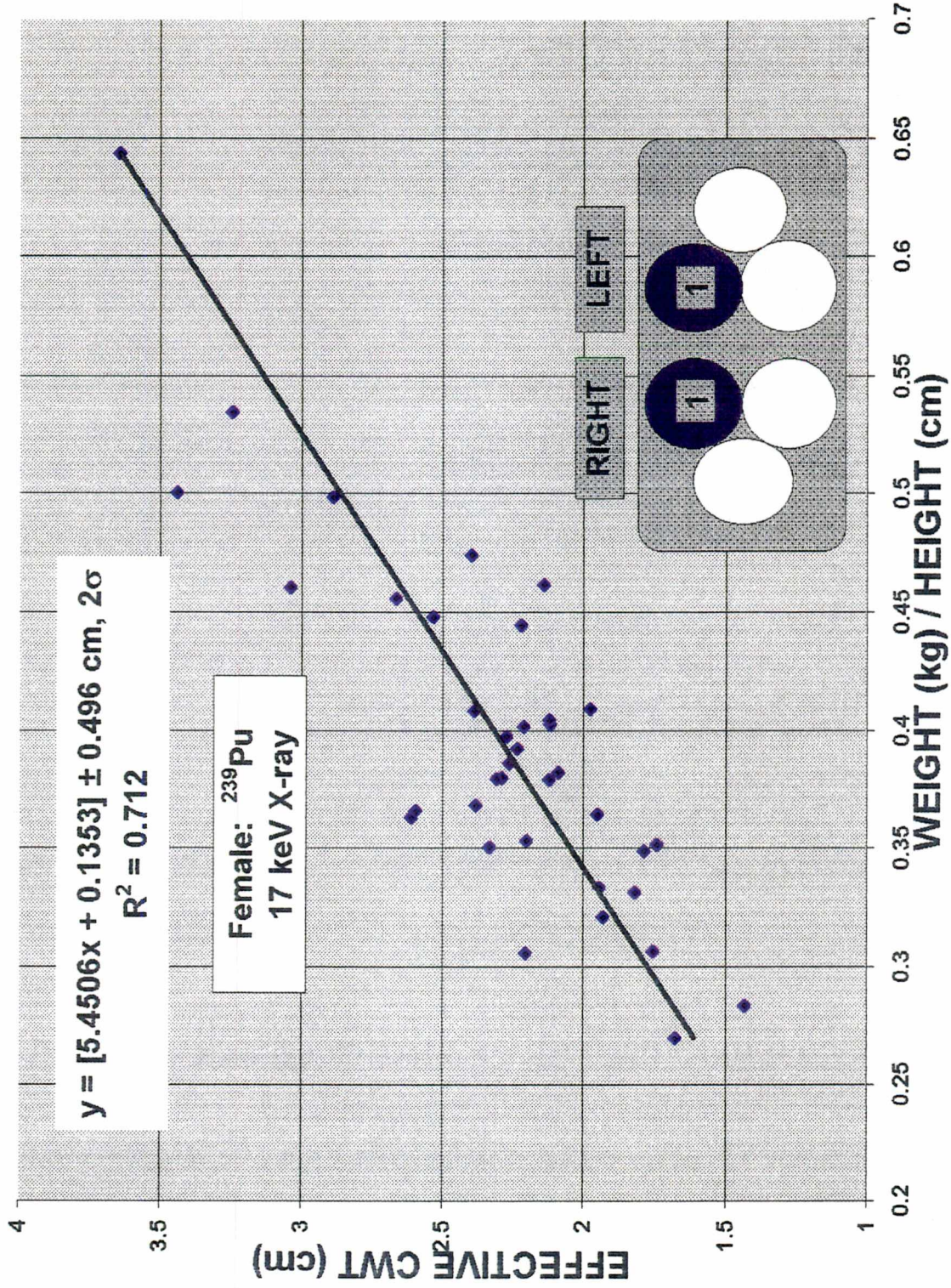



Figure 6-16. Female L1/R1 CWT vs. W/H
Average CWT = 2.30 cm

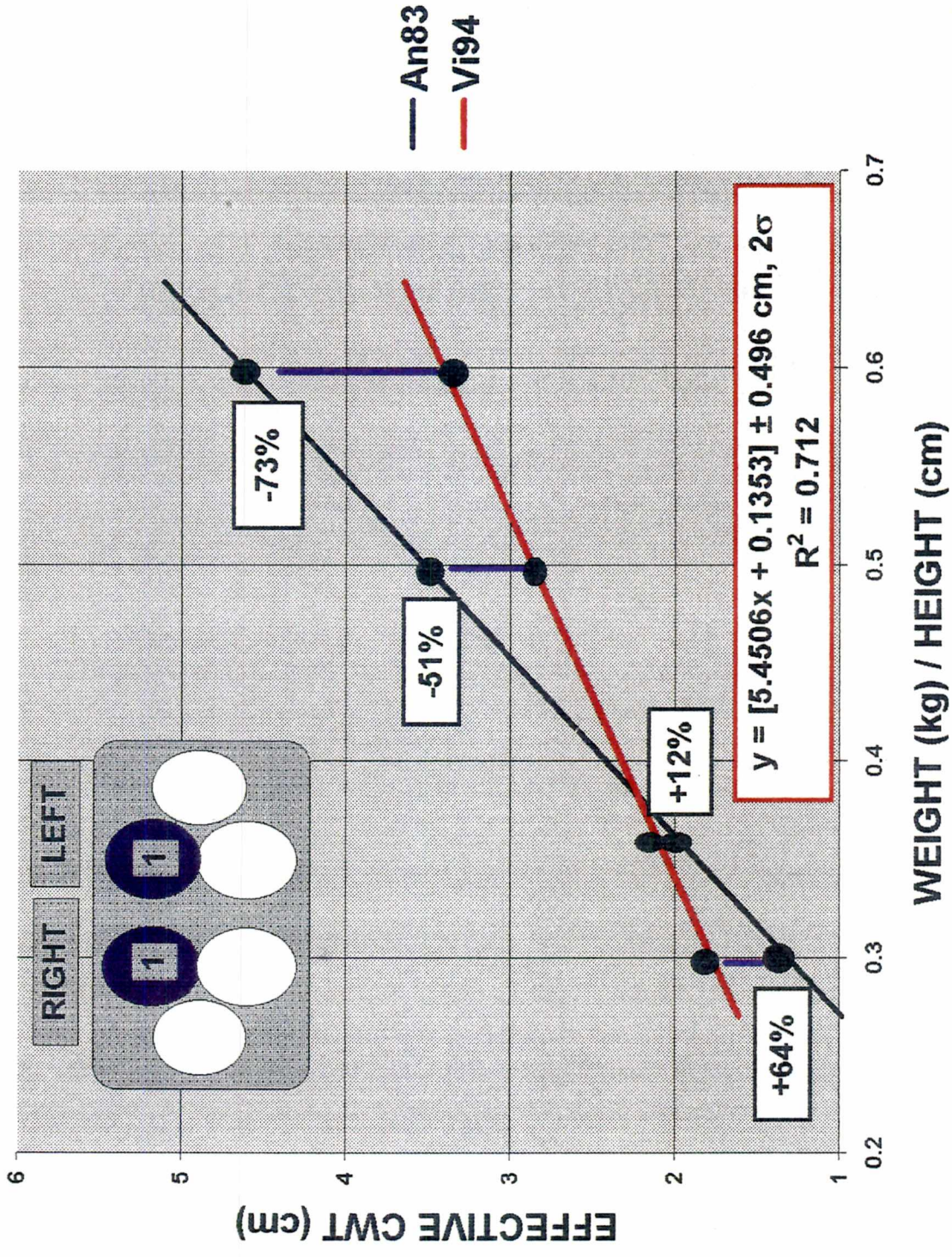



Figure 6-17. Relative Percent Errors in Detection Efficiency Using the Current CWT Equation An83 versus the Female CWT Equation Vi94 Two-Detector Array

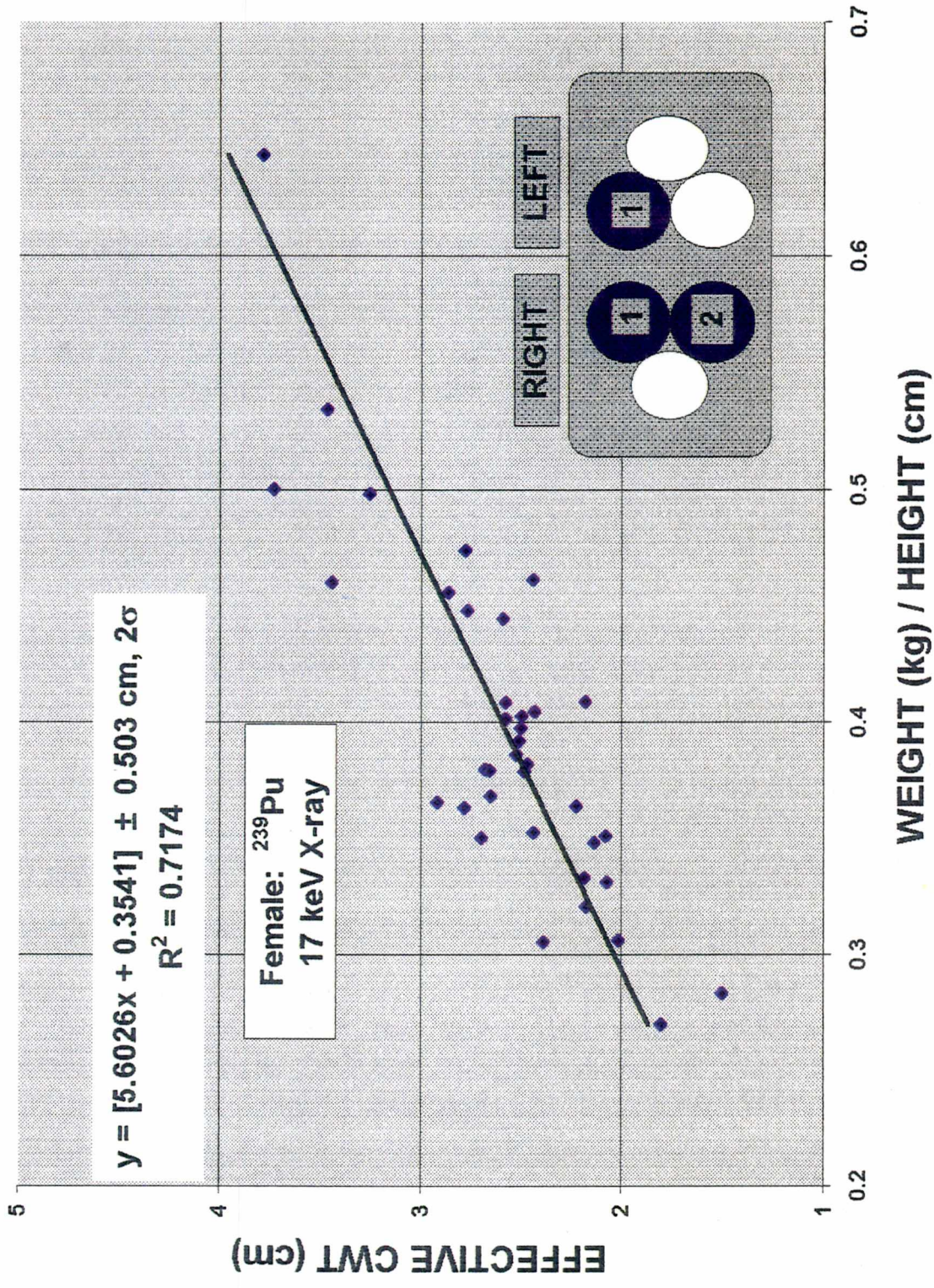



Figure 6-18. Female L1/R1/R2 CWT vs. W/H
Average CWT = 2.57 cm

thickness, this equation would be used to predict a value for the CWT. The standard error at the 95% confidence level of the estimate would be ± 0.503 cm and $R^2$ = 0.7174. If the proposed correlation were used to predict chest wall thicknesses, the largest error would have been + 0.57 cm in an individual whose measured CWT was 3.73 cm and predicted CWT was 3.16 cm. The predicted CWT would have overestimated the efficiency calibration and underestimated the activity (nCi) reported. The percent error in efficiency calibration would have been + 84%. Figure 6-19 shows the relative percent error in detector efficiency calibration of the three-detector HPGe female CWT equation to the present CWT equation (An83) which was derived using the phoswich two-detector array. Figure 6-20 is a summary of the $^{239}$Pu female CWT prediction equations for the two-, three- and six-detector HPGe arrays compared to the An83, Fr80 and De73 CWT prediction equations.

The following results derived for $^{241}$Am 59.5 keV photons and the female total CWT relate to measurements using a standard technique for all 37 subjects. The individual results are plotted in Figure 6-21 as a function of weight/height (kg/cm). Using linear regression analysis, the data could be represented by the function

$$\text{CWT (cm)} = 7.2324(W/H) + 1.4258 \quad \text{(Vi94)}. \qquad (6\text{-}21)$$

The mean effective chest wall thickness was 4.29 cm with a 1$\sigma$-standard deviation of ± 0.641 cm; individual results varied in range from 2.77 to 5.73 cm. In the absence of an ultrasonic measurement of chest wall thickness, this correlation would be used to predict a value of CWT. The standard error at the 95% confidence level of the estimate would be ± 0.714 cm and $R^2$ = 0.6774. If the proposed correlation was used to predict chest wall thicknesses, the largest error would have been + 0.732 cm in an individual whose measured CWT was 4.90 cm and predicted CWT was 4.17 cm. The predicted value would have overestimated the detector efficiency calibration and underestimated the activity (nCi)

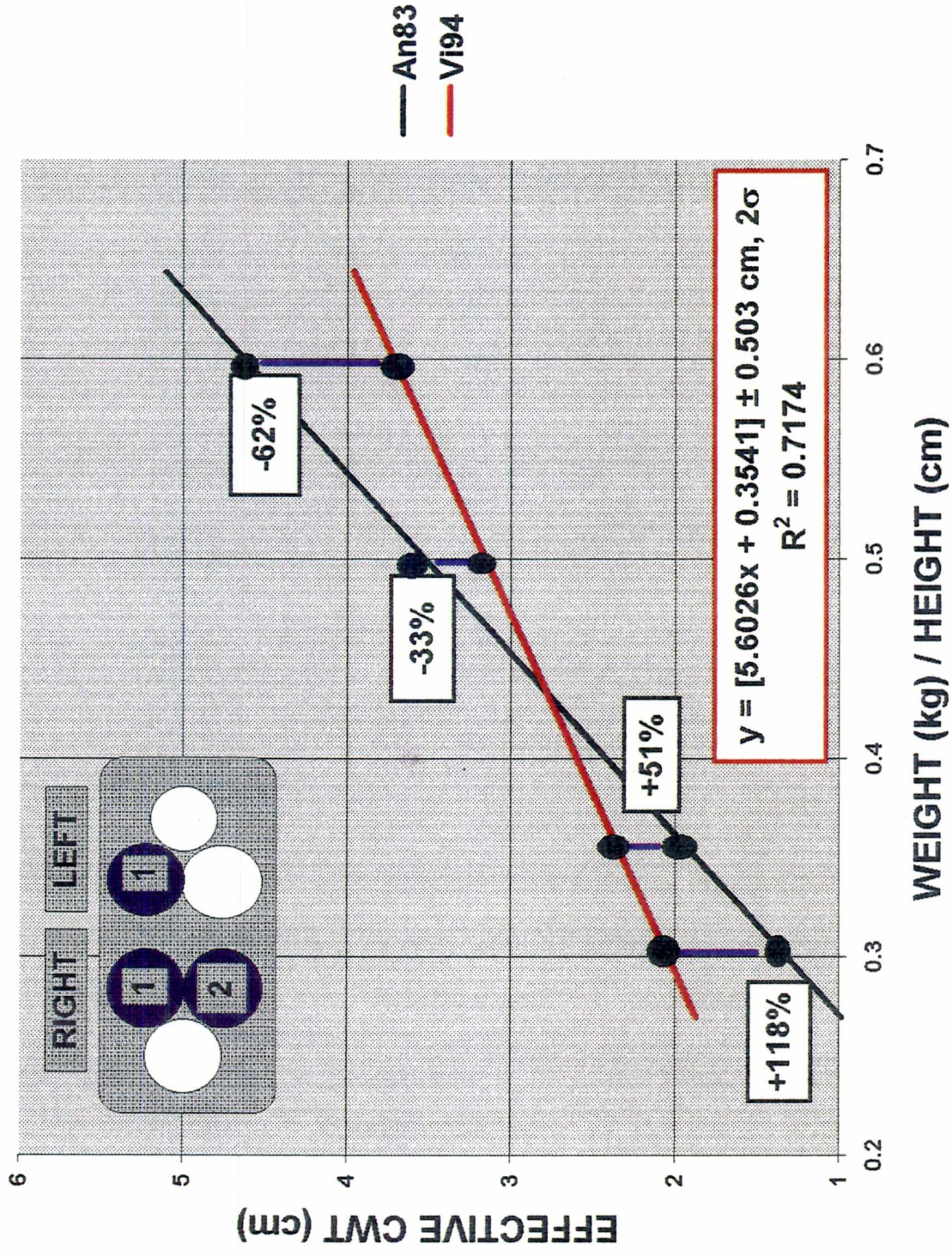



Figure 6-19. Relative Percent Errors in Detection Efficiency Using the Current Equation An83 versus the Female CWT Equation Vi94 Three-Detector Array

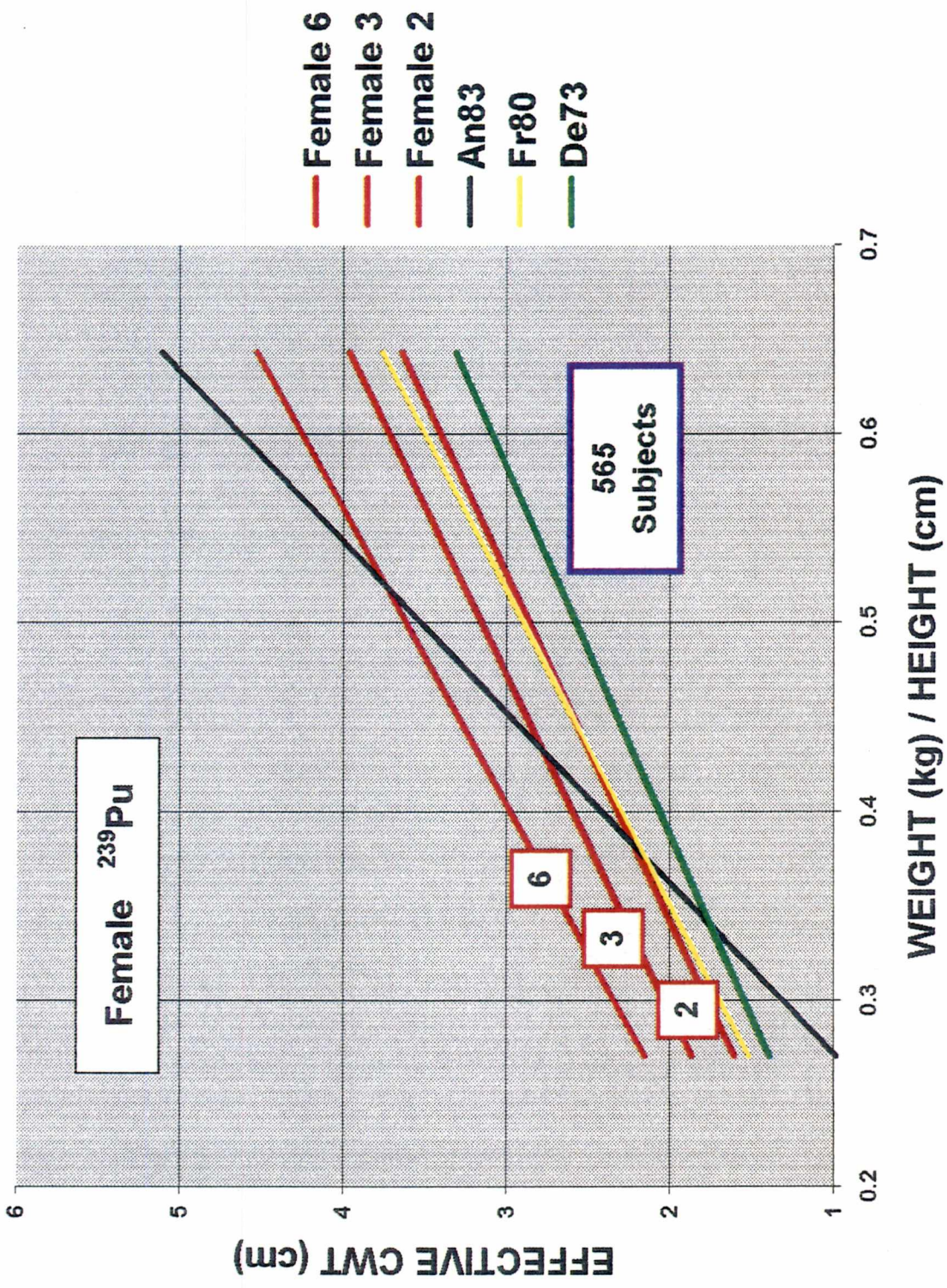



Figure 6-20. Summary of the Female $^{239}$Pu CWT Prediction Equations

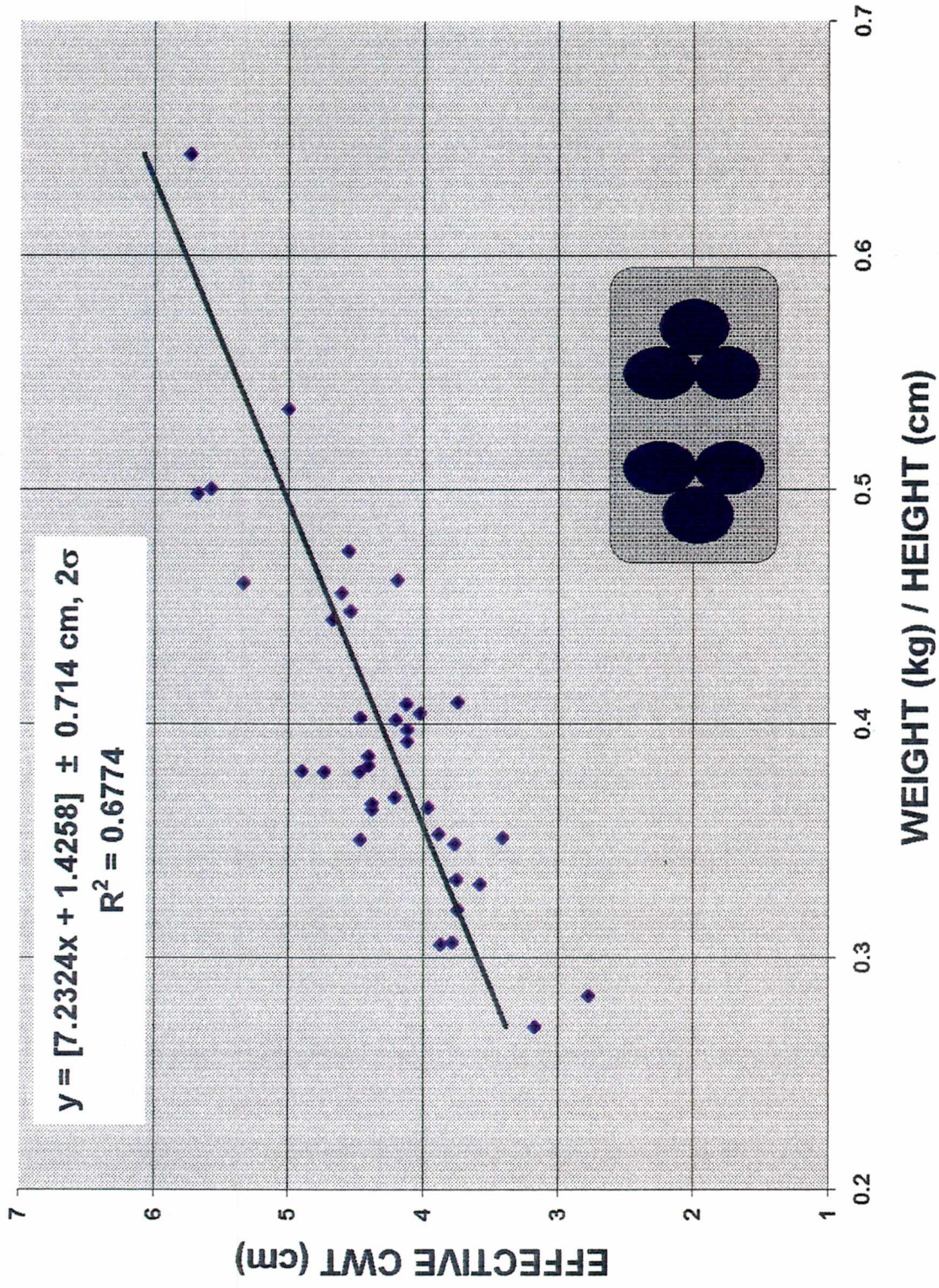



Figure 6-21. Female Total CWT for $^{241}Am$
Average CWT = 4.29 cm

reported within the lungs. The female total CWT for $^{241}$Am 59.5 keV photons was compared only to the An83 phoswich derived CWT equation. Table 6-8 compares some of the measurement technique parameters used for each CWT equation.

Table 6-8. Comparison of female $^{241}$Am measurement technique parameters with An83 CWT equation.

| Parameter | Vi94 | An83 |
|---|---|---|
| Number of subjects | 37 | 33 |
| Position | recline | supine |
| Number of measm'ts/lung | 12 | 6* |
| $\mu$, cm$^{-1}$ | 0.184 | 0.946* |
| $R^2$ | 0.6774 | 0.9* |
| $2\sigma$, cm $\pm$ | 0.714 | 0.642 |
| Mean Eff CWT, cm | 4.29 | 2.8* |

* exact value unavailable; the An83 CWT equation has not been formally published.

The two-detector array describes the L1 and R1 detector positions and the associated derived female CWT prediction equation is given by

$$\text{CWT (cm)} = 5.3486(\text{W/H}) + 0.1683 \quad \text{(Vi94)}. \tag{6-22}$$

Figure 6-22 is a plot of the individual CWT results against the CWT prediction line as a function of the ratio of weight/height (kg/cm). The mean effective CWT was 2.29 cm with a $2\sigma$-standard deviation of $\pm$ 0.499 cm and $R^2 = 0.7006$. The $1\sigma$-standard deviation of the individual measurements was $\pm$ 0.47 cm; individual results varied in range from 1.43 to 3.74 cm. If the proposed correlation was used to predict chest wall thicknesses, the largest error would have been - 0.53 cm in an individual whose measured CWT was 2.11 cm and predicted CWT was 2.64 cm. The predicted value would have underestimated the detector

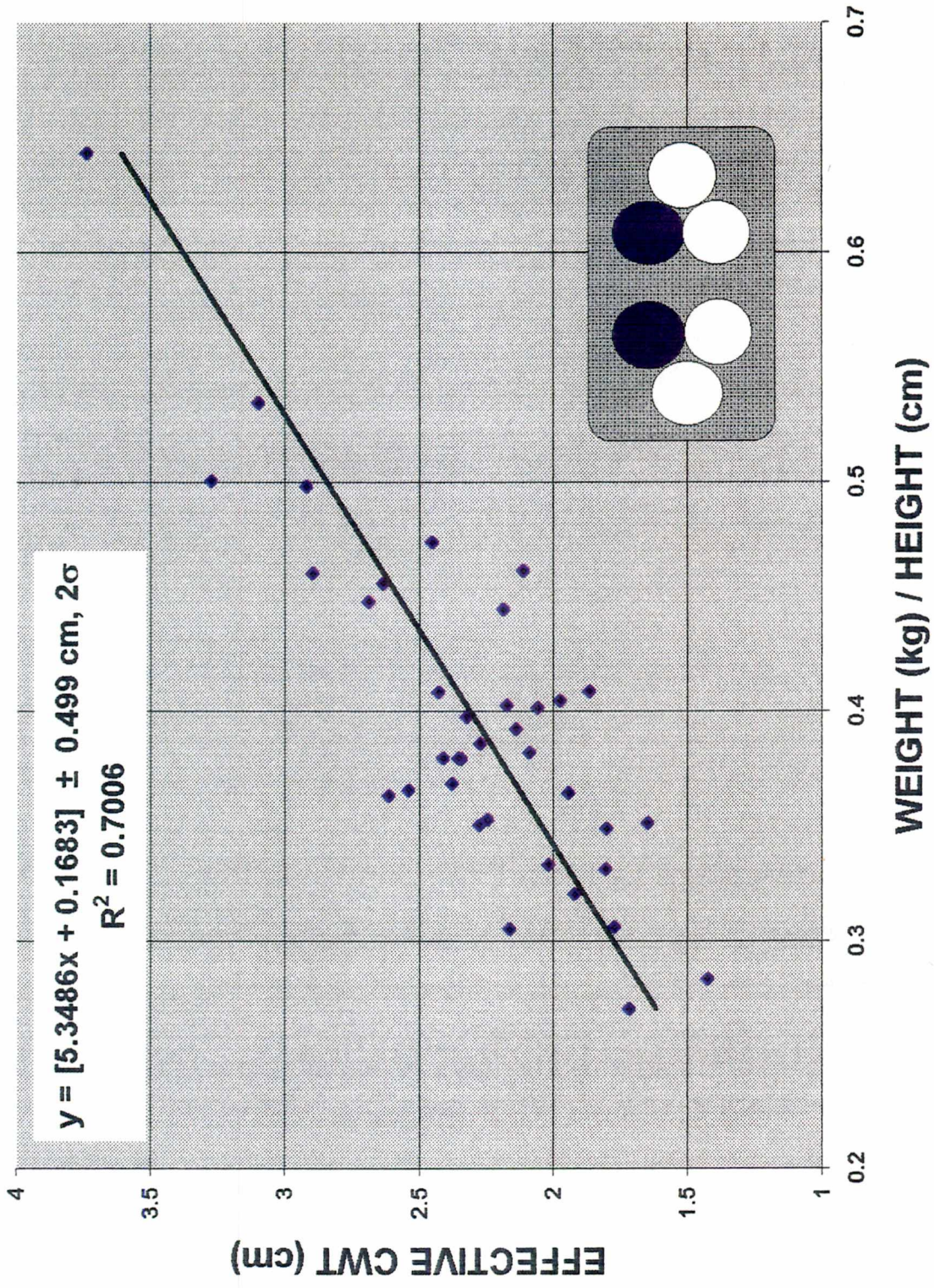



Figure 6-22. Female L1/R1 CWT vs. W/H for $^{241}Am$
Average CWT = 2.29 cm

efficiency calibration and overestimated the activity (nCi) reported within the lungs. The percent error in efficiency calibration would have been - 19%.

The three-detector array describes the L1, R1 and R2 detector positions and the associated derived female CWT prediction equation is given by

$$\text{CWT (cm)} = 5.9554(\text{W/H}) + 0.5025 \quad \text{(Vi94)}. \qquad (6\text{-}23)$$

Figure 6-23 is a plot of the individual results against the CWT prediction line as function of the ratio of weight/height (kg/cm). The mean effective CWT was 2.86 cm with a $1\sigma$-standard deviation of $\pm$ 0.54 cm; individual results varied in range from 1.59 to 3.95 cm. The standard error at the 95% confidence level of the estimate would be $\pm$ 0.628 cm and $R^2 = 0.648$. If the proposed correlation was used to predict chest wall thicknesses, the largest error would have been - 0.69 cm in an individual whose measured CWT was 2.24 cm and predicted CWT was 2.94 cm. The predicted CWT would have underestimated the detector efficiency calibration and overestimated the activity (nCi) reported within the lungs. The percent error in efficiency calibration would have been -22%. Figure 6-24 is a summary of the $^{241}$Am female CWT prediction equations for the two-, three- and six-detector HPGe arrays compared to the An83 CWT prediction equation.

The mean arithmetic female CWT increases by 86% laterally from the detector R1 to R3 positions, and by 85% transversely from the detector R1 to R2 positions. Figure 6-25 shows the increase in CWT laterally and transversely as a plot of the CWTs for each detector position which as a sum encompasses the total chest area measured.

Comparison of Male and Female CWT Equations

It would be ideal to have one CWT prediction equation for male and female subjects for routine lung counting measurements. However, as will be shown, using only the male or female CWT prediction equation ($^{239}$Pu) for both genders would yield significant efficiency

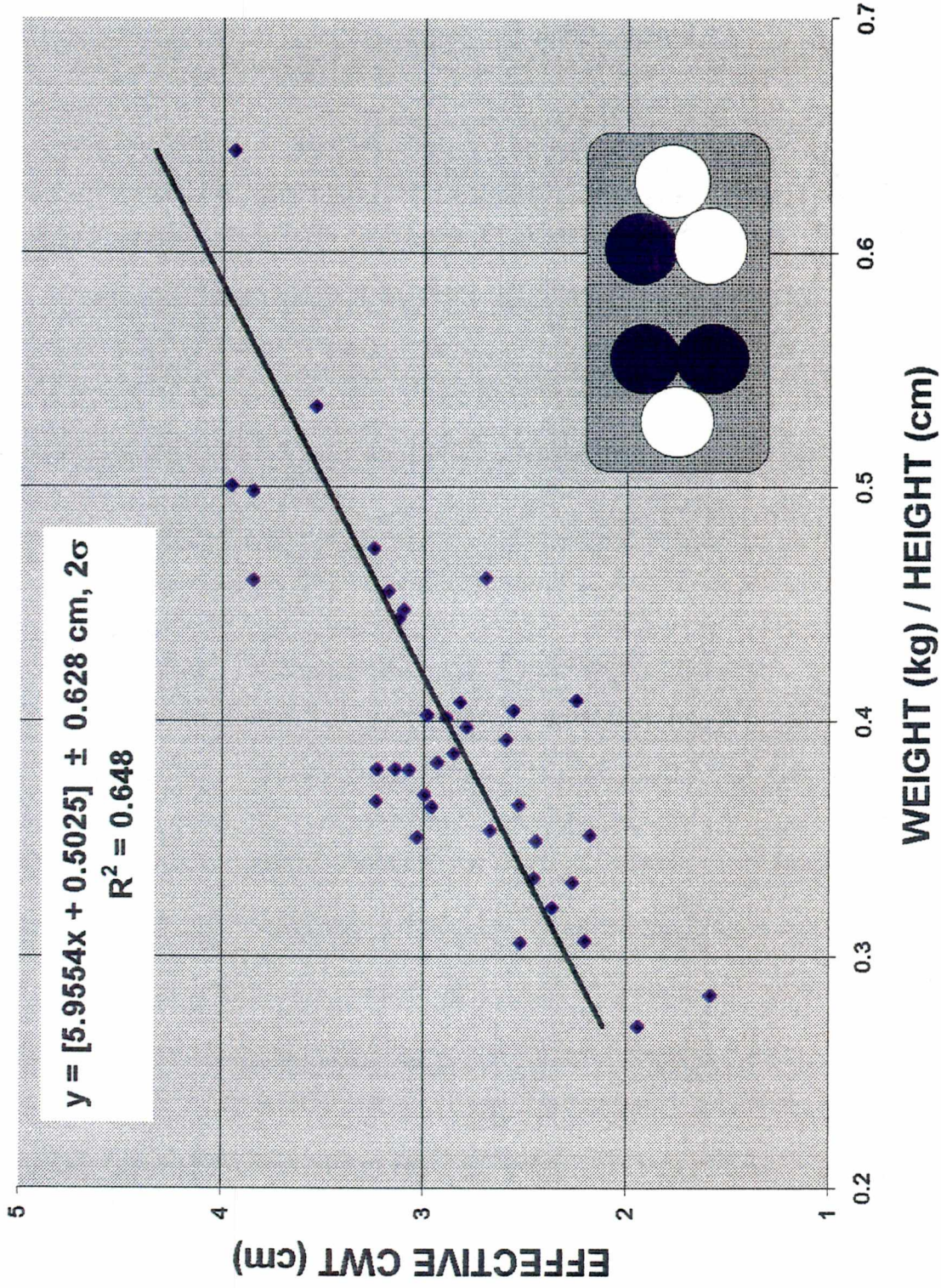



Figure 6-23. Female L1/R1/R2 CWT vs. W/H for $^{241}Am$
Average CWT = 2.86 cm

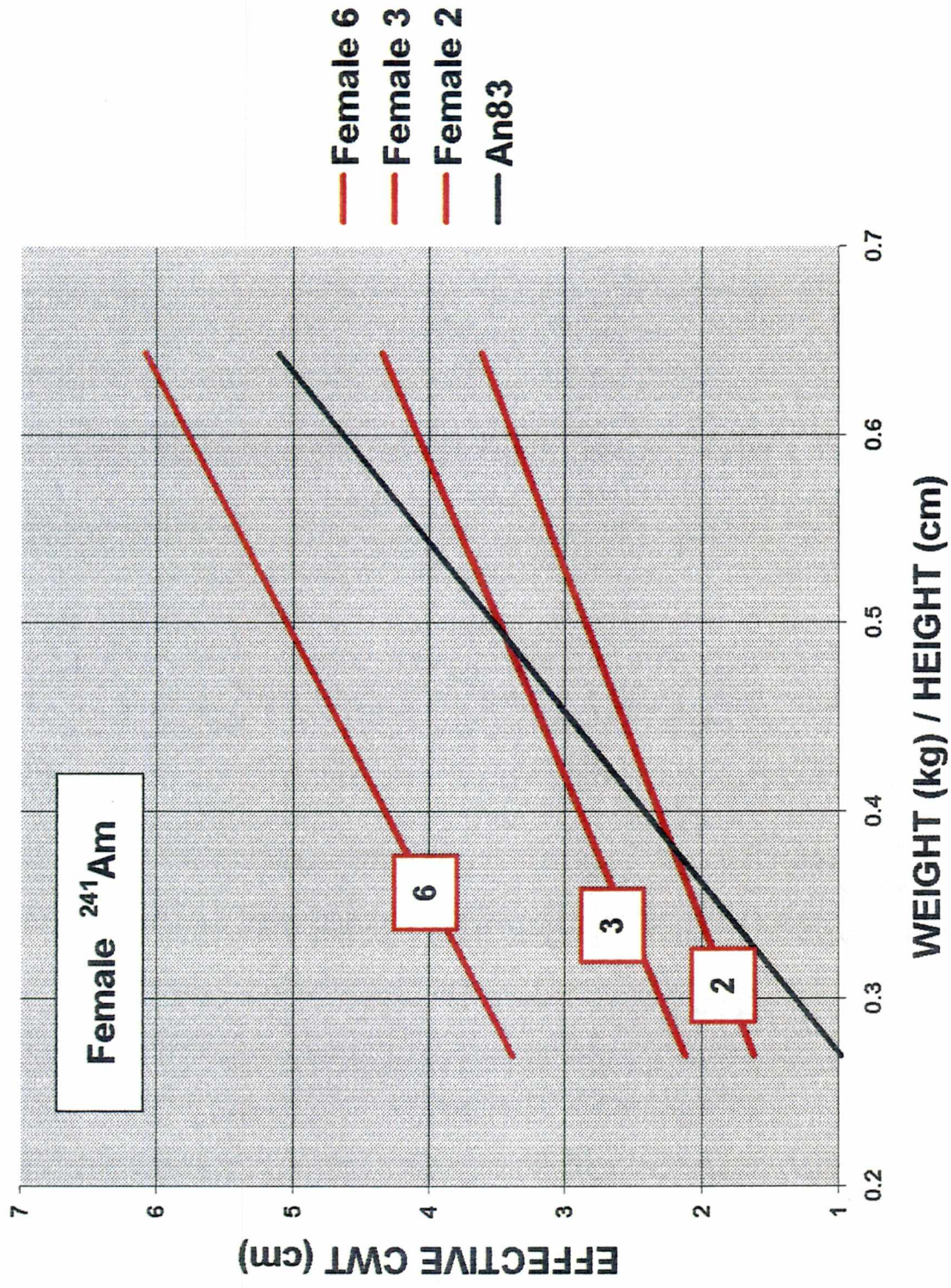



Figure 6-24. Summary of the Female $^{241}$Am CWT Prediction Equations

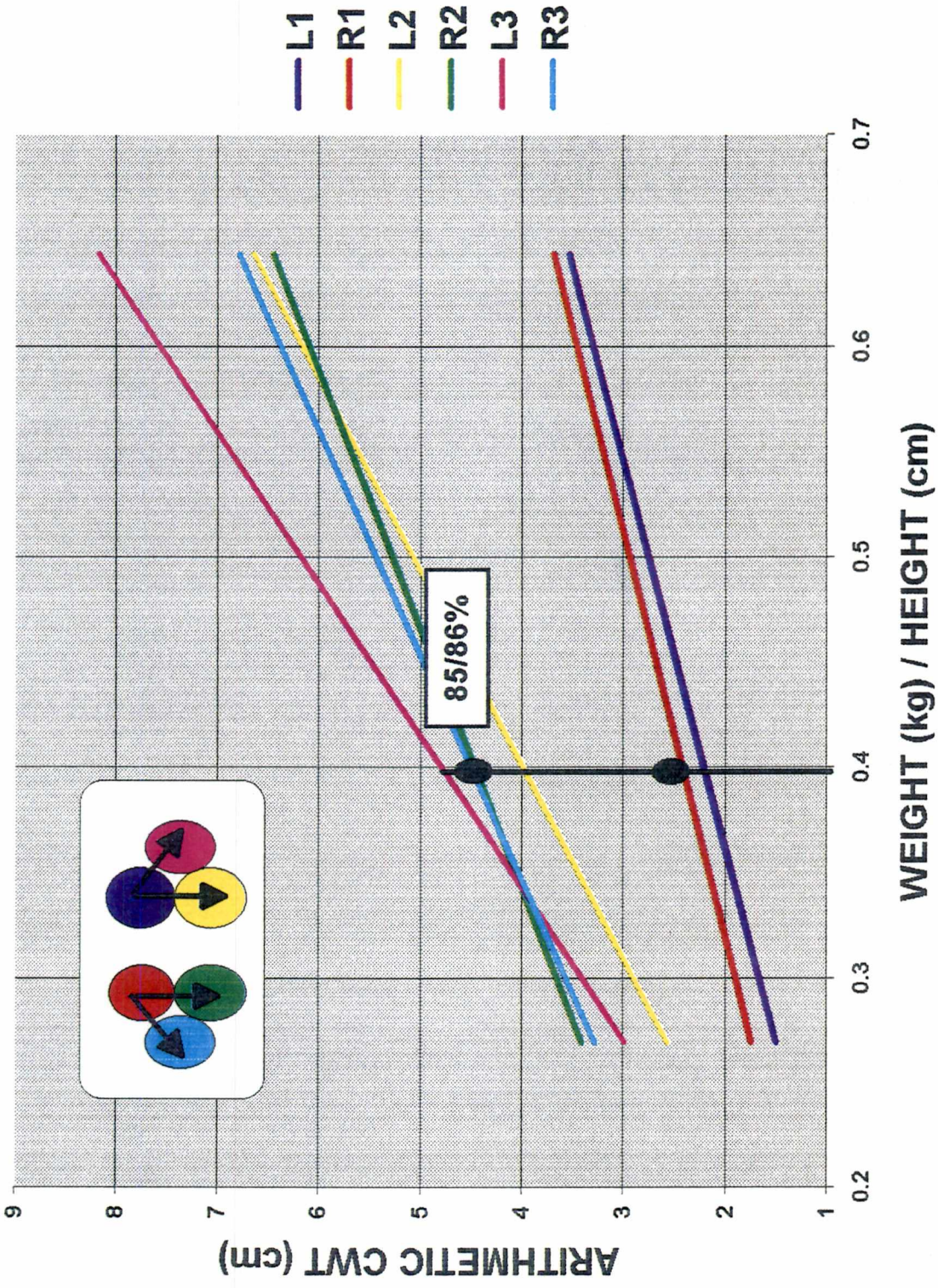



Figure 6-25. Female Arithmetic CWT Increases by 85% Laterally (R1 to R3) and by 86% Transversely (R1 to R2)

calibration errors. The two-detector array is the most comparable of detector configurations analyzed for both male and female subjects due to the similar anatomical structure of the chest area observed (upper thorax) which is considered even or flat for both genders. Therefore, the two-detector array is the array selected for comparison of the male and female CWT prediction equations. According to the tissue data of Reference Male and Reference Female of ICRP 23, the male CWT was more attenuating than the female CWT because of more muscle tissue present (by thickness). The average percentage of muscle of the male CWT was 67% compared to 53% of the female CWT. Also, the female CWT proved less attenuating than the male CWT due to more adipose (breast) tissue present. The average percentage of adipose of the female CWT was 47% compared to 33% of the male CWT. Figure 6-26 shows the male and female two-detector array derived CWT prediction lines and the relative percent errors in detection efficiency for the average female W/H of 0.4 kg/cm and average male W/H of 0.5 kg/cm. Due to the significant relative percent errors in detection efficiency by using either CWT equation for both genders, resulting in gross errors in assessment of a plutonium lung burden, two CWT prediction equations applicable to the gender of the subject should be used in routine lung counting measurements. The male CWT prediction equation selected for routine operations is for the three-detector array and the female CWT prediction equation is for the two-detector array.

**Uncertainty in Male and Female CWT Measurements**

Two male subjects were remeasured to estimate the reproducibility of the CWT measurements. The first subject was measured on two consecutive days, and the second subject was measured with three months elapsed time between the measurements. The CWTs were calculated for the three-detector array. Both subjects' weight and height were constant and contributed no difference between the two measurements. The first subject's

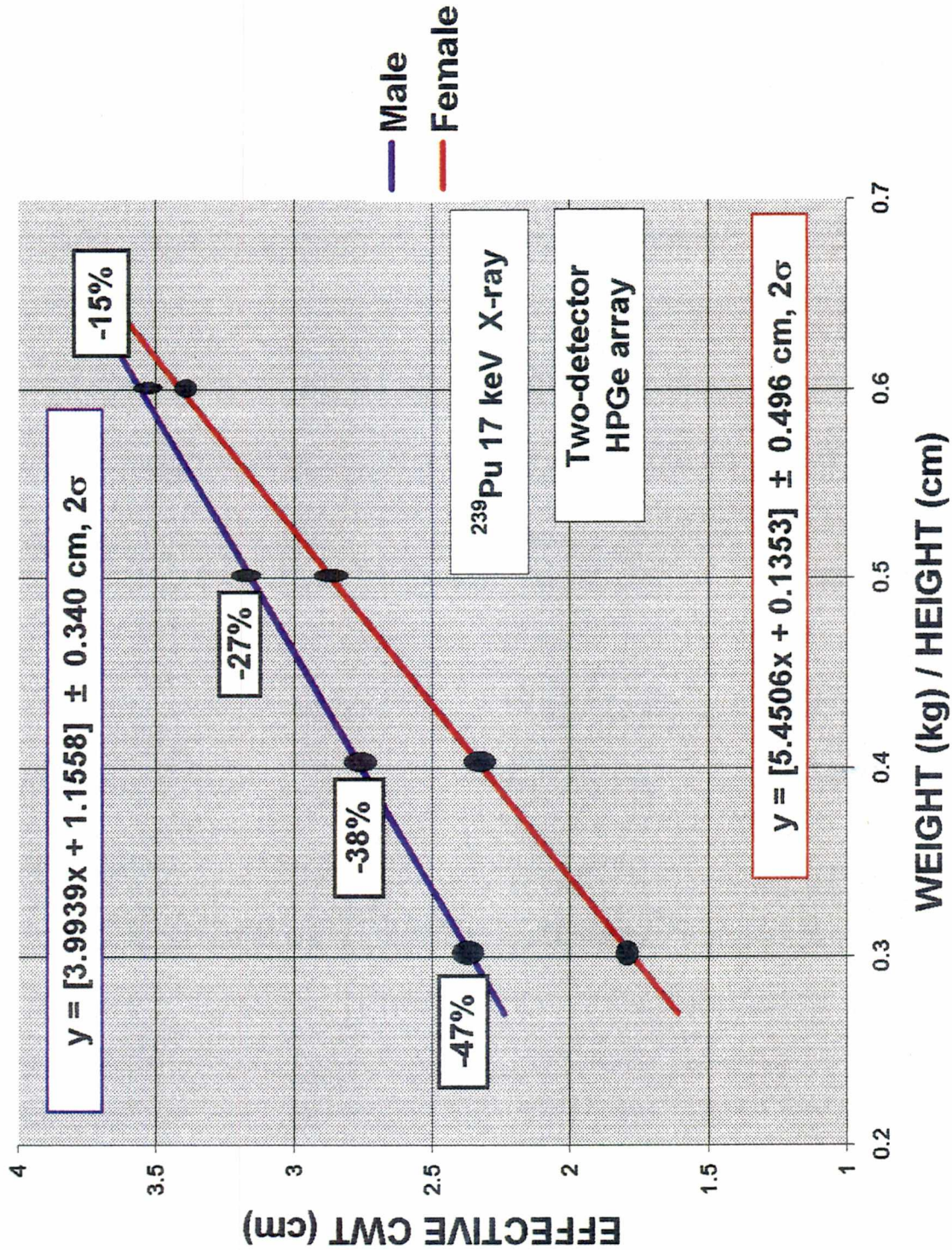



Figure 6-26. Relative Percent Errors in Detection Efficiency of the Male and Female CWT Prediction Equations for the Two-Detector Array

measurement #1 and #2 yielded effective CWTs of 2.49 and 2.58 cm, respectively. Measurement #1 was more detector efficient than #2 by 9%. The second subject's measurement #1 and #2 yielded effective CWTs of 3.43 and 3.44 cm, respectively. Measurement #1 was more detector efficient than #2 by 2%.

Two female subjects were remeasured to estimate the reproducibility of the CWT measurements. The first subject was measured with approximately one month time elapse between measurements. The second subject was measured with approximately two months time elapse between measurements. The CWTs were calculated for the two-detector array. The first subject's measurement #1 and #2 yielded CWTs of 3.11 and 3.48 cm, respectively. The percent difference of the two CWTs was 10%. Measurement #1 was more detector efficient than measurement #2 by 48%. The subject had increased weight by 0.64 kg since the first measurement, thus, yielding a percent difference in W/H of 0.8%. The second subject's measurement #1 and #2 yielded effective CWTs of 3.12 and 3.07 cm, respectively. The percent difference of the two CWT measurements was 1.6%. Measurement #1 was less detector efficient than measurement #2 by - 5%. The subject's weight had increased by 0.18 kg since the first measurement, thus, yielding a percent difference in W/H of 0.3%.

A significant reason for the small variation in measurement #1 and #2 CWTs is due to the relatively small area of the thorax scanned during any one set of measurements, it is most unlikely that when the subject returns for a second assessment that the transducer will be placed in exactly the same positions as on the first occasion. Uncertainty in the estimation of the chest wall thickness from an ultrasonic measurement excluding statistical uncertainties in the data analysis are attributed to the following sources of uncertainty in the measurement: 1) operator technique of applying too much or too little pressure to the thorax with the transducer probe, thus producing poor image resolution and uncertainty in identifying the

tissue interfaces, and 2) limited by the ultrasonic system electronic caliper resolution of ±1 mm. The total uncertainty in the ultrasonic measurement of the chest wall thickness due to the above sources of uncertainty is estimated to be ± 2 mm. Considering the average male W/H of 0.5 kg/cm, and using the CWT prediction equation for the two-detector array to estimate CWTs, the total error in the chest wall thickness value would have been about ± 5.4 mm, which corresponds to a total uncertainty (statistical and technique) of approximately ± 20% in the predicted CWT value. Also, using the CWT prediction equation for the three-detector array to estimate CWTs, the total error in the CWT value would have been about ± 5.5 mm, which corresponds to a total uncertainty (statistical and technique) of approximately ± 20%. Both total uncertainties of ± 20% are within the allowable maximum total uncertainty in chest wall thickness value of ± 50% as specified by ANSI-N13.30:1987. Considering the average female W/H of 0.4 kg/cm, and using the CWT prediction equation for the two-detector array to estimate CWTs, the total error in the chest wall thickness estimate would have been ± 6.7 mm, which corresponds to a total uncertainty (statistical and technique) of approximately ± 30%. Also, using the CWT prediction equation for the three-detector array to estimate CWTs, the total error in the CWT value would have been ± 7.0 mm, which corresponds to a total uncertainty of approximately ± 30%. Both total uncertainties of ± 30% are within the allowable maximum total uncertainty in CWT.

# CHAPTER 7

## CONCLUSION

The present CWT prediction equation (An83), derived using a dual phoswich detection system, with male subjects only positioned supine and not accounting for the adipose or muscle thicknesses of the total intercostal tissue thickness, is not applicable for estimating the male and female CWT for two or three HPGe detector arrays due to the significant relative percent errors in detection efficiency calibration. Therefore, this results in gross errors of the final plutonium lung burden estimates.

The comparison of the male and female CWT equations for the two-detector array, determined significant relative percent errors in using only one gender-specific CWT equation for both genders. Therefore, a gender-specific CWT equation as provided by this research is recommended.

According to the anatomy of the calibration torso phantom, the area of the lungs observed by the three-detector array during a lung count measurement is the greatest of the three detector configurations analyzed, therefore, it is the detector configuration along with the derived CWT prediction equation selected for use in routine lung counting measurements of male subjects. The male CWT prediction equation for routine lung counting measurements is given by

$$\text{CWT (cm)} = [4.3379(W/H) + 1.2513] \pm 0.350 \text{ cm}, 2\sigma \text{ (Vi94)} \qquad (7\text{-}1)$$

The two-detector array yielded the thinnest CWT for male and female subjects and as a result, the two-detector array yields the highest detection efficiency. In addition, it is the most comparable detector array among female subjects. Therefore, the two-detector array

and the derived female CWT prediction equation are selected for use in routine lung counting measurements of female subjects. The female CWT prediction equation for routine lung counting measurements is given by

$$\text{CWT (cm)} = [5.4506(W/H) + 0.1353] \pm 0.496 \text{ cm}, 2\sigma \text{ (Vi94)} \qquad (7\text{-}2)$$

Figure 7-1 shows the comparison in detection efficiency calibration of the routine male and female CWT prediction equations against the present CWT prediction equation (An83). Figure 7-2 shows a summary comparison of relative percent error of CWT between all of the CWT prediction equations of this research for the six-detector HPGe array with the An83 CWT prediction equation. Figure 7-3 shows a summary comparison of relative percent error in detection efficiency for all of the CWT prediction equations of this research for the two-detector HPGe array with the An83 CWT prediction equation. Figure 7-4 shows a summary comparison of relative percent error in detection efficiency for all of the CWT prediction equations of this research for the three-detector HPGe array with the An83 CWT prediction equation.

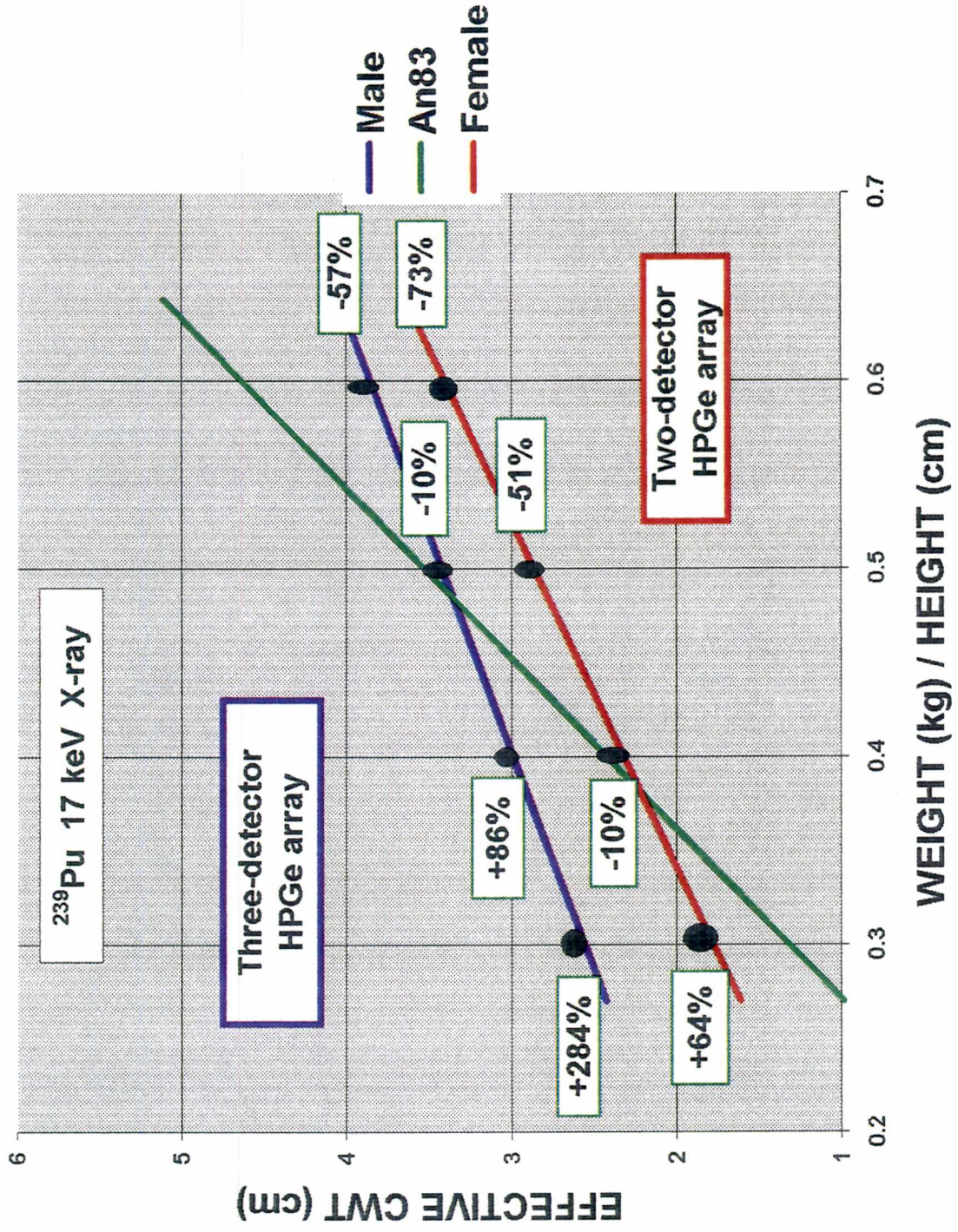



Figure 7-1. Male and Female CWT Prediction Equations for Routine Lung Counting Measurements Compared to the An83 Equation and the Relative Percent Errors in Detection Efficiency

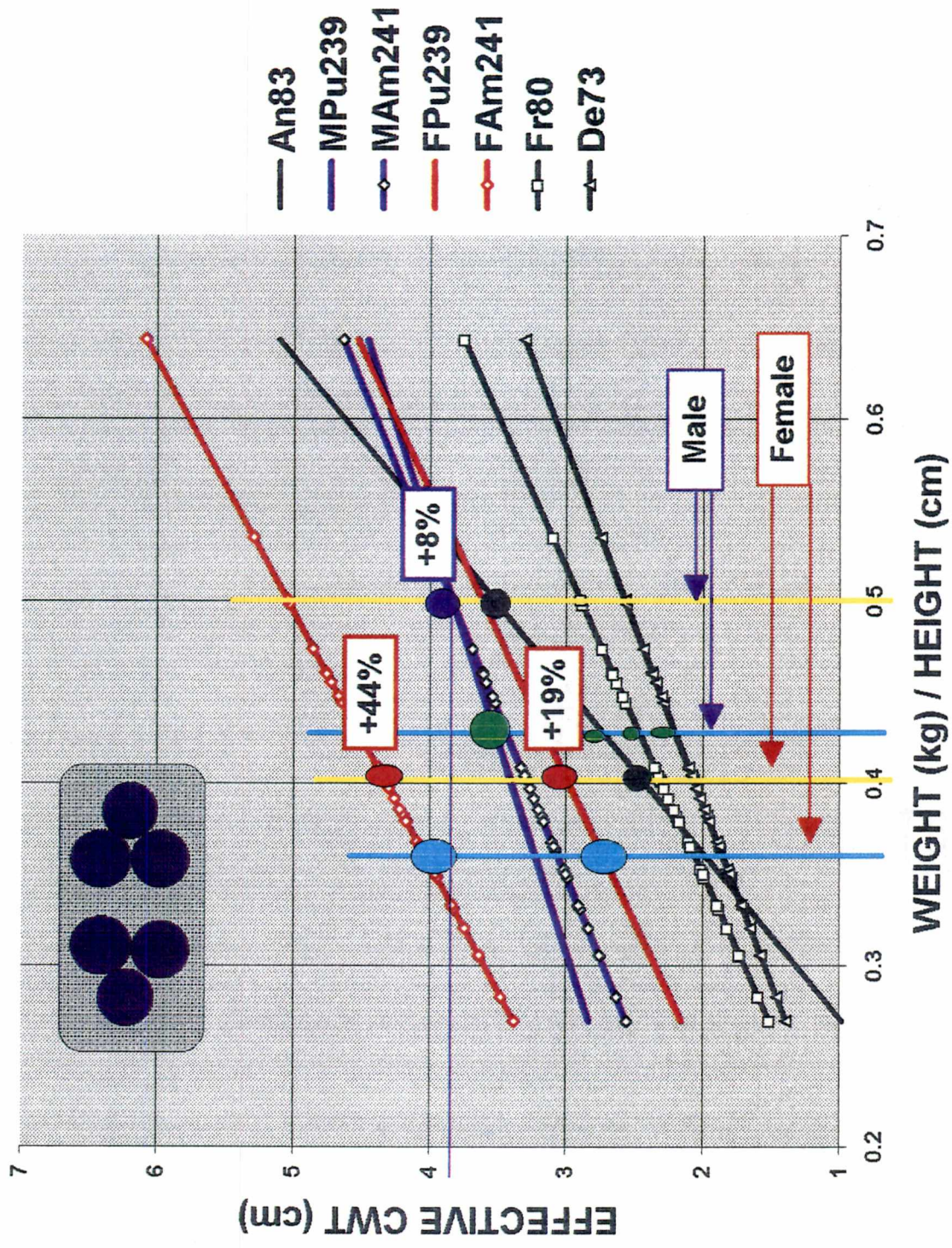



Figure 7-2. Summary of Male and Female Total CWT Prediction Equations
Relative Percent Errors in CWT

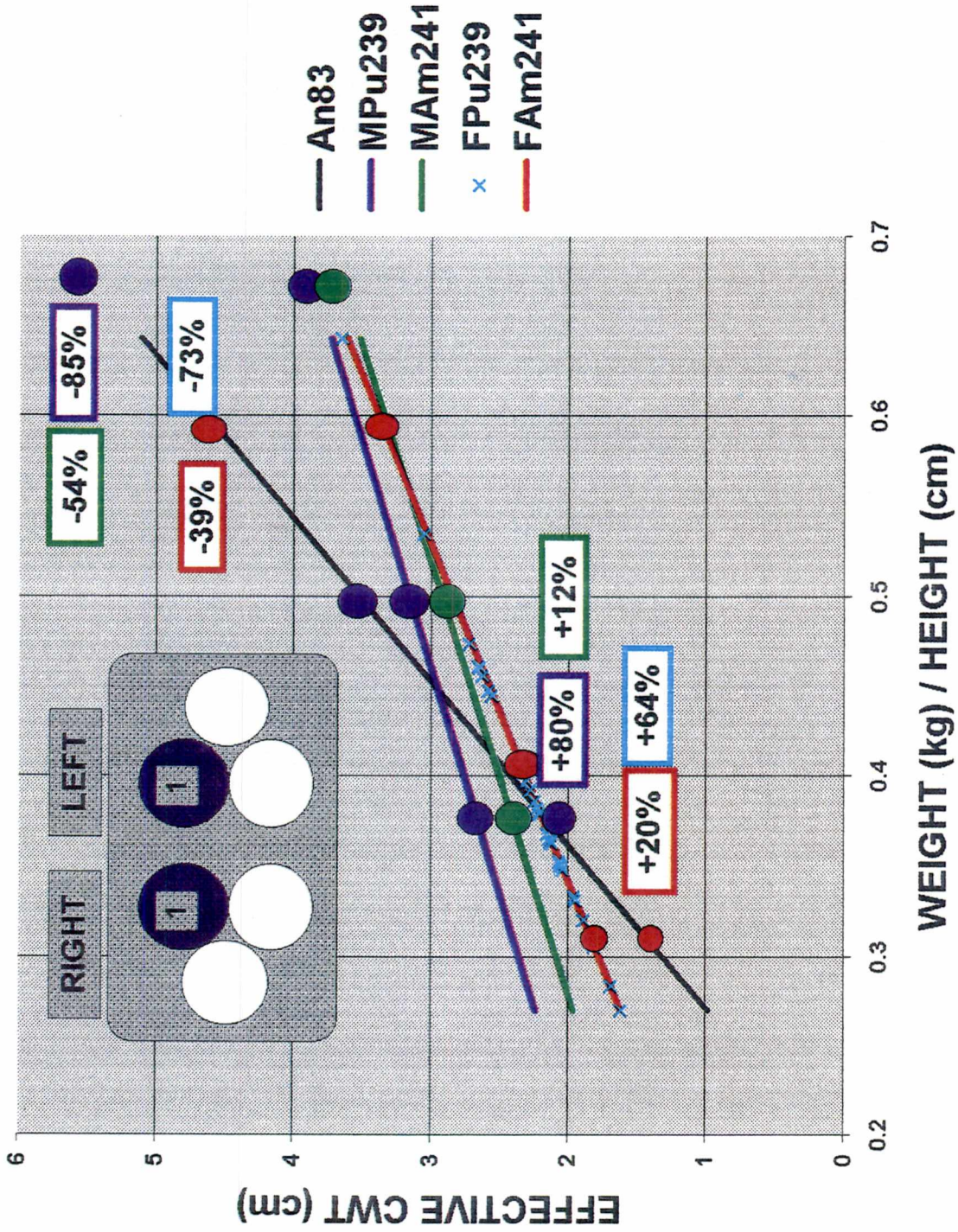



Figure 7-3. Summary of Male and Female L1/R1 CWT Prediction Equations Relative Percent Errors in Detection Efficiency

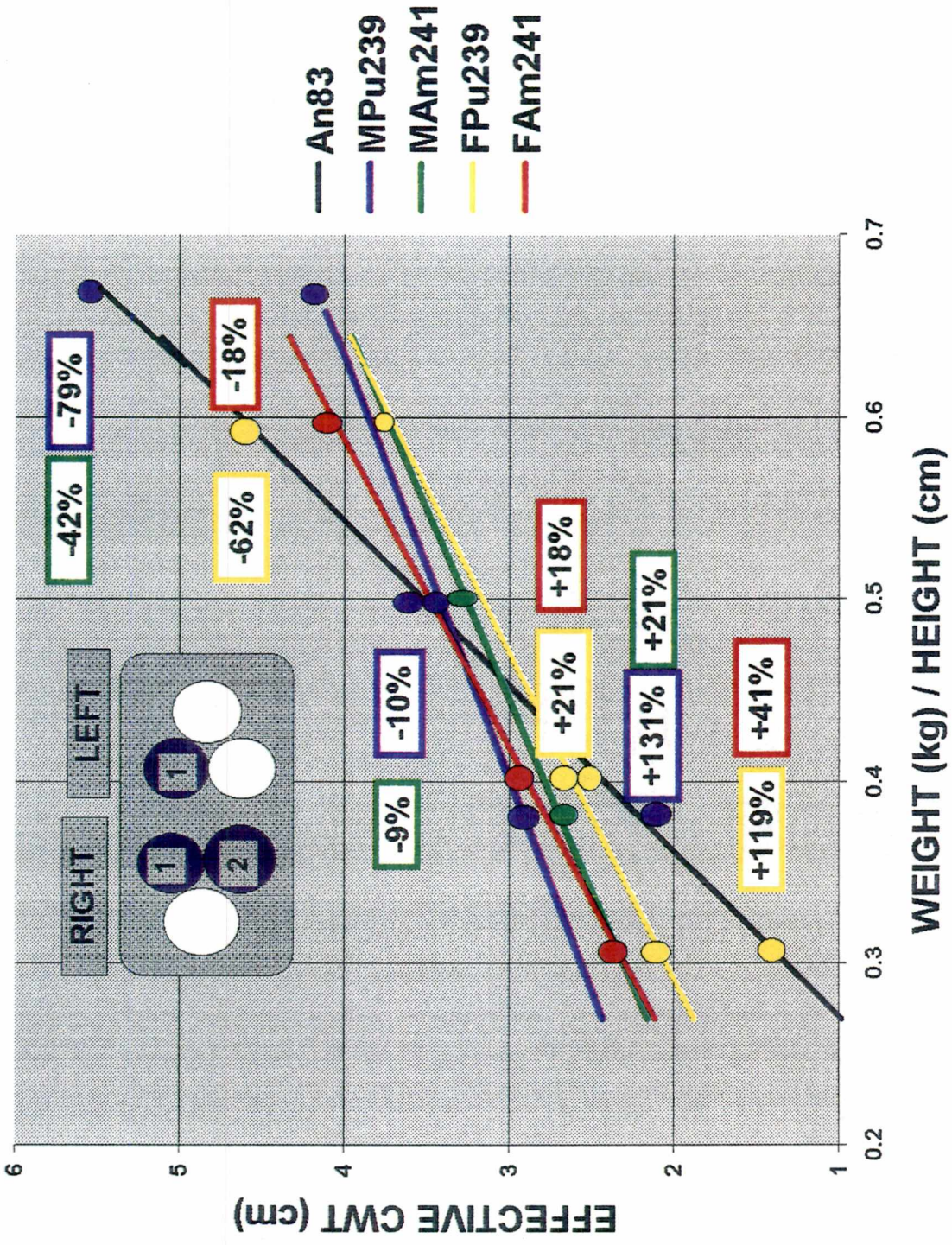



Figure 7-4. Summary of Male and Female L1/R1/R2 CWT Prediction Equations Relative Percent Errors in Detection Efficiency

# LIST OF REFERENCES

## LIST OF REFERENCES


An94 Anderson, A.L.; Personal communication concerning the CWT equation he derived, which is in use by the majority of the U.S. Department of Energy lung counting facilities.

An83 Anderson, A.L. of Lawrence Livermore National Laboratory, author of chest wall thickness prediction equation presently in use by the majority of the U.S. Department of Energy lung counting facilities; see Ca89 for description of equation.

Be85 Berger, C.D.; Lane, B.H. "Biometric Estimation of Chest Wall Thickness of Females." *Health Physics*, **49**, pp.419-424 (September 1985).

Ca89 Canberra Nuclear/Nuclear Data VAX/VMS Germanium Lung Counting Package User's Manual 07-0424 pp.41-42,51 Canberra Industries, Inc., (January 1989).

Ch84 Chilton, A.B.; Shultis, J.K.; Faw, R.E. Principles of Radiation Shielding pp.147-153 Prentice-Hall, Inc., (1984).

De73 Dean, P.N. "Estimation of Chest Wall Thickness in Lung Counting for Plutonium." *Health Physics*, **24**, pp.439-441 (April 1973).

Fr80 Fry, F.A.; Sumerling, T. "Measurement of Chest Wall Thickness for Assessment of Plutonium in Human Lungs." *Health Physics*, **39**, pp.89-92 (July 1980).

ICRP75 International Commission on Radiological Protection, 1975, Publication 23: Report of the Task Group on Reference Man Pergamon Press, Inc., (1975).

Ka93 Kang, C.; Newton, D.; Warner, A.J.; Absolom, T.A.; Kruchten, D.A.; Anderson, A.L.; Palmer, H.E. "A Comparison of Techniques in the Assessment of Chest Wall Thickness and Composition." *Health Physics*, **64**, pp.406-411 (April 1993).

Kr90 Kruchten, D.A.; Anderson, A.L. "Improved Ultrasonic Measurement Techniques Applied to Assay of Pu and Other Transuranics in Lung." *Health Physics*, **59**, pp.117-123 (July 1990).

K25 The K-25 Site Lung Counter, two-detector HPGe array efficiency calibration documentation.

Kr94 Kruchten, D.A.; Personal communication concerning her publication Kr90 and the current CWT equation derived at LLNL.

Mi77 Miller,Jr., F. College Physics pp.230-255 Harcourt Brace Jovanovich, Inc., 4th Edition (1977).

Ne78[1] Newton, D.; Taylor, B.T.; Anderson, A.L. "X-ray Counting Efficiencies for Plutonium in Lungs, Derived From Studies with Inhaled Palladium-103." *Health Physics*, **35**, pp.573-585 (June 1978).

Ne78[2] Newton, D.; White, D.R. "Attenuation of 13-20 keV Photons in Tissue Substitutes and Their Validity for Calibration Purposes in the Assessment of Plutonium in Lungs." *Health Physics*, **35**, pp.699-703 (November 1978).

ORNL94 The Oak Ridge National Laboratory Whole Body Couting Laboratory, three-detector HPGe array efficiency calibration documentation.

Pa89 Palmer, H.E.; Rieksts, G.A.; Jefferies, S.J.; Gunston, K.J. "Improved Counting Efficiencies for Measuring $^{239}$Pu in the Lung in the Sitting Position." *Health Physics*, **57**, pp.747-752 (November 1989).

Ra94 Rao, G.R., the Internal Dosimetry Group Leader at the Oak Ridge National Laboratory; Personal communication concerning the thesis subject matter and technical analysis of the ultrasound measurements data.

Si80 Siemens Gammasonics, Inc., Operation Manual Model 2300 PHO/SONIC* Series 2000 Linear Array Dynamic Imaging System *Registered Trademark Siemens Gammasonics, Inc., (October 1980).

Su82 Sumerling, T.J.; Quant, S.P. "Measurements of the Human Anterior Chest Wall By Ultrasound and Estimates of Chest Wall Thickness for Use in Determination of Transuranic Nuclides in the Lung." *Radiation Protection Dosimetry*, **3**, pp.203-210 (1982).

Tu86 Turner, J.E. Atoms, Radiation, and Radiation Protection Chapter 7 Pergamon Press, Inc., (1986).

Vi94 Vickers, L.R. author of this thesis prepared for the Nuclear Engineering Department at the University of Tennessee.

Wa94 Watts, J.R. of the Internal Dosimetry Group at the Oak Ridge National Laboratory; Personal communication concerning the thesis subject matter and technical analysis of the ultrasound measurements data.

# APPENDICES

# APPENDIX A

## MALE SUBJECT ULTRASOUND DATA

| | | |
|---|---|---|
| Name | 1 | M |
| Age | 33 | y |
| Height | 66.25 | in |
| Weight | 159.00 | lb |

Values are in (mm)

| Detector | Scan | Fat 1 | Fat 2 | Favg | Tot | Tot 2 | TotAvg | MuscAvg |
|---|---|---|---|---|---|---|---|---|
| Left 1 | 1 | 6 | 7 | 6.5 | 23 | 24 | 23.5 | 17.0 |
| | 2 | 5 | 7 | 6.0 | 24 | 28 | 26.0 | 20.0 |
| Left 3 | 1 | 9 | 11 | 10.0 | 42 | 37 | 39.5 | 29.5 |
| | 2 | 11 | 12 | 11.5 | 45 | 37 | 41.0 | 29.5 |
| Left 2 | 1 | 7 | 7 | 7.0 | 33 | 31 | 32.0 | 25.0 |
| | 2 | 11 | 11 | 11.0 | 29 | 32 | 30.5 | 19.5 |
| Right 1 | 1 | 4 | 7 | 5.5 | 25 | 25 | 25.0 | 19.5 |
| | 2 | 4 | 7 | 5.5 | 23 | 26 | 24.5 | 19.0 |
| Right 3 | 1 | 10 | 12 | 11.0 | 39 | 40 | 39.5 | 28.5 |
| | 2 | 13 | 12 | 12.5 | 47 | 39 | 43.0 | 30.5 |
| Right 2 | 1 | 5 | 6 | 5.5 | 28 | 30 | 29.0 | 23.5 |
| | 2 | 8 | 9 | 8.5 | 32 | 32 | 32.0 | 23.5 |

| | | |
|---|---|---|
| Name | 2 | M |
| Age | 31 | y |
| Height | 68.25 | in |
| Weight | 199.00 | lb |

| Detector | Scan | Fat 1 | Fat 2 | FatAvg | Tot | Tot 2 | TotAvg | MuscAvg |
|---|---|---|---|---|---|---|---|---|
| Left 1 | 1 | 3 | 8 | 5.5 | 21 | 23 | 22 | 16.5 |
| | 2 | 2 | 5 | 3.5 | 22 | 29 | 25.5 | 22 |
| Left 3 | 1 | 5 | 7 | 6 | 37 | 37 | 37 | 31 |
| | 2 | 2 | 3 | 2.5 | 37 | 31 | 34 | 31.5 |
| Left 2 | 1 | 12 | 10 | 11 | 32 | 33 | 32.5 | 21.5 |
| | 2 | 11 | 12 | 11.5 | 32 | 36 | 34 | 22.5 |
| Right 1 | 1 | 7 | 10 | 8.5 | 24 | 29 | 26.5 | 18 |
| | 2 | 6 | 12 | 9 | 23 | 28 | 25.5 | 16.5 |
| Right 3 | 1 | 8 | 14 | 11 | 40 | 37 | 38.5 | 27.5 |
| | 2 | 10 | 14 | 12 | 42 | 47 | 44.5 | 32.5 |
| Right 2 | 1 | 9 | 12 | 10.5 | 32 | 40 | 36 | 25.5 |
| | 2 | 12 | 12 | 12 | 40 | 42 | 41 | 29 |

| | | |
|---|---|---|
| Name | 3 | M |
| Age | 27 | y |
| Height | 74.50 | in |
| Weight | 209.80 | lb |

| Detector | Scan | Fat 1 | Fat 2 | FatAvg | Tot | Tot 2 | TotAvg | MuscAvg |
|---|---|---|---|---|---|---|---|---|
| Left 1 | 1 | 9 | 10 | 9.5 | 30 | 27 | 28.5 | 19 |
| | 2 | 10 | 10 | 10 | 27 | 30 | 28.5 | 18.5 |
| Left 3 | 1 | 13 | 16 | 14.5 | 50 | 49 | 49.5 | 35 |
| | 2 | 19 | 20 | 19.5 | 55 | 54 | 54.5 | 35 |
| Left 2 | 1 | 11 | 12 | 11.5 | 37 | 36 | 36.5 | 25 |
| | 2 | 13 | 15 | 14 | 42 | 44 | 43 | 29 |
| Right 1 | 1 | 11 | 11 | 11 | 33 | 33 | 33 | 22 |
| | 2 | 15 | 13 | 14 | 29 | 32 | 30.5 | 16.5 |
| Right 3 | 1 | 12 | 19 | 15.5 | 48 | 54 | 51 | 35.5 |
| | 2 | 14 | 19 | 16.5 | 52 | 57 | 54.5 | 38 |
| Right 2 | 1 | 12 | 13 | 12.5 | 37 | 41 | 39 | 26.5 |
| | 2 | 12 | 13 | 12.5 | 42 | 46 | 44 | 31.5 |

| | | | |
|---|---|---|---|
| Name | 4 | M | |
| Age | 51 | y | Values are in (mm) |
| Height | 74.75 | in | |
| Weight | 202.80 | lb | |

| Detector | Scan | Fat 1 | Fat 2 | FatAvg | Tot | Tot 2 | TotAvg | MuscAvg |
|---|---|---|---|---|---|---|---|---|
| Left 1 | 1 | 9 | 12 | 10.5 | 24 | 30 | 27 | 16.5 |
| | 2 | 11 | 9 | 10 | 26 | 29 | 27.5 | 17.5 |
| Left 3 | 1 | 13 | 10 | 11.5 | 40 | 42 | 41 | 29.5 |
| | 2 | 15 | 12 | 13.5 | 43 | 44 | 43.5 | 30 |
| Left 2 | 1 | 8 | 7 | 7.5 | 32 | 34 | 33 | 25.5 |
| | 2 | 9 | 9 | 9 | 30 | 32 | 31 | 22 |
| Right 1 | 1 | 10 | 10 | 10 | 26 | 32 | 29 | 19 |
| | 2 | 11 | 12 | 11.5 | 27 | 31 | 29 | 17.5 |
| Right 3 | 1 | 13 | 14 | 13.5 | 44 | 52 | 48 | 34.5 |
| | 2 | 12 | 14 | 13 | 47 | 56 | 51.5 | 38.5 |
| Right 2 | 1 | 15 | 9 | 12 | 39 | 40 | 39.5 | 27.5 |
| | 2 | 17 | 18 | 17.5 | 37 | 40 | 38.5 | 21 |

| | | | |
|---|---|---|---|
| Name | 5 | M | |
| Age | 47 | y | |
| Height | 64.50 | in | |
| Weight | 154.20 | lb | |

| Detector | Scan | Fat 1 | Fat 2 | FatAvg | Tot | Tot 2 | TotAvg | MuscAvg |
|---|---|---|---|---|---|---|---|---|
| Left 1 | 1 | 7 | 8 | 7.5 | 22 | 30 | 26 | 18.5 |
| | 2 | 8 | 11 | 9.5 | 24 | 32 | 28 | 18.5 |
| Left 3 | 1 | 12 | 17 | 14.5 | 40 | 41 | 40.5 | 26 |
| | 2 | 12 | 15 | 13.5 | 41 | 37 | 39 | 25.5 |
| Left 2 | 1 | 12 | 11 | 11.5 | 25 | 24 | 24.5 | 13 |
| | 2 | 11 | 10 | 10.5 | 36 | 37 | 36.5 | 26 |
| Right 1 | 1 | 7 | 10 | 8.5 | 22 | 29 | 25.5 | 17 |
| | 2 | 7 | 11 | 9 | 22 | 30 | 26 | 17 |
| Right 3 | 1 | 11 | 14 | 12.5 | 37 | 42 | 39.5 | 27 |
| | 2 | 12 | 12 | 12 | 40 | 42 | 41 | 29 |
| Right 2 | 1 | 13 | 14 | 13.5 | 35 | 33 | 34 | 20.5 |
| | 2 | 12 | 12 | 12 | 37 | 36 | 36.5 | 24.5 |

| | | | |
|---|---|---|---|
| Name | 6 | M | |
| Age | 62 | y | |
| Height | 70.25 | in | |
| Weight | 284.80 | lb | |

| Detector | Scan | Fat 1 | Fat 2 | FatAvg | Tot | Tot 2 | TotAvg | MuscAvg |
|---|---|---|---|---|---|---|---|---|
| Left 1 | 1 | 17 | 16 | 16.5 | 37 | 39 | 38 | 21.5 |
| | 2 | 22 | 22 | 22 | 39 | 42 | 40.5 | 18.5 |
| Left 3 | 1 | 22 | 21 | 21.5 | 62 | 64 | 63 | 41.5 |
| | 2 | 25 | 22 | 23.5 | 67 | 71 | 69 | 45.5 |
| Left 2 | 1 | 23 | 27 | 25 | 47 | 54 | 50.5 | 25.5 |
| | 2 | 32 | 35 | 33.5 | 48 | 49 | 48.5 | 15 |
| Right 1 | 1 | 17 | 19 | 18 | 43 | 38 | 40.5 | 22.5 |
| | 2 | 19 | 22 | 20.5 | 40 | 43 | 41.5 | 21 |
| Right 3 | 1 | 21 | 20 | 20.5 | 60 | 68 | 64 | 43.5 |
| | 2 | 30 | 40 | 35 | 62 | 69 | 65.5 | 30.5 |
| Right 2 | 1 | 29 | 31 | 30 | 52 | 55 | 53.5 | 23.5 |
| | 2 | 30 | 32 | 31 | 52 | 55 | 53.5 | 22.5 |

| | | | |
|---|---|---|---|
| Name | 7 | M | |
| Age | 31 | y | Values are in (mm) |
| Height | 70.50 | in | |
| Weight | 188.00 | lb | |

| Detector | Scan | Fat 1 | Fat 2 | FatAvg | Tot | Tot 2 | TotAvg | MuscAvg |
|---|---|---|---|---|---|---|---|---|
| Left 1 | 1 | 11 | 10 | 10.5 | 27 | 27 | 27 | 16.5 |
| | 2 | 16 | 17 | 16.5 | 33 | 38 | 35.5 | 19 |
| Left 3 | 1 | 19 | 26 | 22.5 | 48 | 53 | 50.5 | 28 |
| | 2 | 17 | 20 | 18.5 | 49 | 52 | 50.5 | 32 |
| Left 2 | 1 | 18 | 18 | 18 | 37 | 38 | 37.5 | 19.5 |
| | 2 | 22 | 21 | 21.5 | 43 | 42 | 42.5 | 21 |
| Right 1 | 1 | 12 | 12 | 12 | 29 | 35 | 32 | 20 |
| | 2 | 13 | 14 | 13.5 | 30 | 33 | 31.5 | 18 |
| Right 3 | 1 | 20 | 23 | 21.5 | 47 | 52 | 49.5 | 28 |
| | 2 | 18 | 23 | 20.5 | 49 | 51 | 50 | 29.5 |
| Right 2 | 1 | 22 | 15 | 18.5 | 44 | 42 | 43 | 24.5 |
| | 2 | 26 | 26 | 26 | 47 | 46 | 46.5 | 20.5 |

| | | |
|---|---|---|
| Name | 8 | M |
| Age | 34 | y |
| Height | 73.00 | in |
| Weight | 224.00 | lb |

| Detector | Scan | Fat 1 | Fat 2 | FatAvg | Tot | Tot 2 | TotAvg | MuscAvg |
|---|---|---|---|---|---|---|---|---|
| Left 1 | 1 | 12 | 17 | 14.5 | 27 | 32 | 29.5 | 15 |
| | 2 | 15 | 17 | 16 | 29 | 34 | 31.5 | 15.5 |
| Left 3 | 1 | 17 | 14 | 15.5 | 57 | 60 | 58.5 | 43 |
| | 2 | 17 | 17 | 17 | 62 | 61 | 61.5 | 44.5 |
| Left 2 | 1 | 19 | 22 | 20.5 | 37 | 41 | 39 | 18.5 |
| | 2 | 27 | 27 | 27 | 43 | 46 | 44.5 | 17.5 |
| Right 1 | 1 | 10 | 9 | 9.5 | 24 | 27 | 25.5 | 16 |
| | 2 | 12 | 11 | 11.5 | 28 | 33 | 30.5 | 19 |
| Right 3 | 1 | 27 | 33 | 30 | 54 | 59 | 56.5 | 26.5 |
| | 2 | 24 | 27 | 25.5 | 58 | 61 | 59.5 | 34 |
| Right 2 | 1 | 10 | 10 | 10 | 36 | 41 | 38.5 | 28.5 |
| | 2 | 13 | 13 | 13 | 42 | 46 | 44 | 31 |

| | | |
|---|---|---|
| Name | 9 | M |
| Age | 51 | y |
| Height | 64.50 | in |
| Weight | 158.60 | lb |

| Detector | Scan | Fat 1 | Fat 2 | FatAvg | Tot | Tot 2 | TotAvg | MuscAvg |
|---|---|---|---|---|---|---|---|---|
| Left 1 | 1 | 7 | 9 | 8 | 28 | 32 | 30 | 22 |
| | 2 | 9 | 10 | 9.5 | 30 | 34 | 32 | 22.5 |
| Left 3 | 1 | 15 | 15 | 15 | 45 | 46 | 45.5 | 30.5 |
| | 2 | 16 | 22 | 19 | 52 | 47 | 49.5 | 30.5 |
| Left 2 | 1 | 11 | 9 | 10 | 37 | 37 | 37 | 27 |
| | 2 | 14 | 10 | 12 | 36 | 37 | 36.5 | 24.5 |
| Right 1 | 1 | 8 | 9 | 8.5 | 24 | 27 | 25.5 | 17 |
| | 2 | 7 | 8 | 7.5 | 23 | 26 | 24.5 | 17 |
| Right 3 | 1 | 10 | 10 | 10 | 39 | 43 | 41 | 31 |
| | 2 | 11 | 11 | 11 | 41 | 42 | 41.5 | 30.5 |
| Right 2 | 1 | 10 | 14 | 12 | 37 | 38 | 37.5 | 25.5 |
| | 2 | 11 | 9 | 10 | 37 | 37 | 37 | 27 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Name | 10 | M | | | | | | |
| Age | 46 | y | Values are in (mm) | | | | | |
| Height | 70.75 | in | | | | | | |
| Weight | 171.60 | lb | | | | | | |
| | | | | | | | | |
| Detector | Scan | Fat 1 | Fat 2 | FatAvg | Tot | Tot 2 | TotAvg | MuscAvg |
| Left 1 | 1 | 7 | 9 | 8 | 26 | 31 | 28.5 | 20.5 |
| | 2 | 10 | 12 | 11 | 26 | 30 | 28 | 17 |
| Left 3 | 1 | 20 | 24 | 22 | 42 | 44 | 43 | 21 |
| | 2 | 16 | 19 | 17.5 | 54 | 52 | 53 | 35.5 |
| Left 2 | 1 | 9 | 12 | 10.5 | 31 | 32 | 31.5 | 21 |
| | 2 | 16 | 15 | 15.5 | 39 | 38 | 38.5 | 23 |
| Right 1 | 1 | 10 | 9 | 9.5 | 23 | 28 | 25.5 | 16 |
| | 2 | 9 | 8 | 8.5 | 26 | 31 | 28.5 | 20 |
| Right 3 | 1 | 20 | 22 | 21 | 47 | 49 | 48 | 27 |
| | 2 | 22 | 22 | 22 | 47 | 50 | 48.5 | 26.5 |
| Right 2 | 1 | 15 | 13 | 14 | 39 | 40 | 39.5 | 25.5 |
| | 2 | 19 | 17 | 18 | 45 | 45 | 45 | 27 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Name | 11 | M | | | | | | |
| Age | 39 | y | | | | | | |
| Height | 72.00 | in | | | | | | |
| Weight | 175.60 | lb | | | | | | |
| | | | | | | | | |
| Detector | Scan | Fat 1 | Fat 2 | FatAvg | Tot | Tot 2 | TotAvg | MuscAvg |
| Left 1 | 1 | 5 | 6 | 5.5 | 23 | 26 | 24.5 | 19 |
| | 2 | 7 | 7 | 7 | 23 | 26 | 24.5 | 17.5 |
| Left 3 | 1 | 9 | 17 | 13 | 37 | 42 | 39.5 | 26.5 |
| | 2 | 7 | 6 | 6.5 | 29 | 32 | 30.5 | 24 |
| Left 2 | 1 | 10 | 9 | 9.5 | 31 | 31 | 31 | 21.5 |
| | 2 | 12 | 10 | 11 | 32 | 32 | 32 | 21 |
| Right 1 | 1 | 12 | 16 | 14 | 24 | 27 | 25.5 | 11.5 |
| | 2 | 5 | 7 | 6 | 20 | 25 | 22.5 | 16.5 |
| Right 3 | 1 | 10 | 11 | 10.5 | 39 | 37 | 38 | 27.5 |
| | 2 | 10 | 9 | 9.5 | 41 | 47 | 44 | 34.5 |
| Right 2 | 1 | 9 | 7 | 8 | 32 | 33 | 32.5 | 24.5 |
| | 2 | 9 | 7 | 8 | 31 | 32 | 31.5 | 23.5 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Name | 12 | M | | | | | | |
| Age | 45 | y | | | | | | |
| Height | 69.00 | in | | | | | | |
| Weight | 181.60 | lb | | | | | | |
| | | | | | | | | |
| Detector | Scan | Fat 1 | Fat 2 | FatAvg | Tot | Tot 2 | TotAvg | MuscAvg |
| Left 1 | 1 | 9 | 14 | 11.5 | 25 | 32 | 28.5 | 17 |
| | 2 | 12 | 17 | 14.5 | 27 | 31 | 29 | 14.5 |
| Left 3 | 1 | 20 | 25 | 22.5 | 42 | 40 | 41 | 18.5 |
| | 2 | 18 | 22 | 20 | 48 | 47 | 47.5 | 27.5 |
| Left 2 | 1 | 18 | 24 | 21 | 42 | 47 | 44.5 | 23.5 |
| | 2 | 15 | 20 | 17.5 | 39 | 50 | 44.5 | 27 |
| Right 1 | 1 | 12 | 11 | 11.5 | 30 | 31 | 30.5 | 19 |
| | 2 | 9 | 9 | 9 | 24 | 28 | 26 | 17 |
| Right 3 | 1 | 18 | 22 | 20 | 34 | 38 | 36 | 16 |
| | 2 | 14 | 20 | 17 | 42 | 44 | 43 | 26 |
| Right 2 | 1 | 14 | 11 | 12.5 | 33 | 33 | 33 | 20.5 |
| | 2 | 16 | 14 | 15 | 37 | 38 | 37.5 | 22.5 |

| | | |
|---|---|---|
| Name | 13 | M |
| Age | 71.5 | y |
| Height | 67.50 | in |
| Weight | 184.20 | lb |

Values are in (mm)

| Detector | Scan | Fat 1 | Fat 2 | FatAvg | Tot 1 | Tot 2 | TotAvg | MuscAvg |
|---|---|---|---|---|---|---|---|---|
| Left 1 | 1 | 13 | 15 | 14 | 25 | 35 | 30 | 16 |
| | 2 | 16 | 17 | 16.5 | 29 | 39 | 34 | 17.5 |
| Left 3 | 1 | 19 | 22 | 20.5 | 57 | 66 | 61.5 | 41 |
| | 2 | 42 | 47 | 44.5 | 67 | 72 | 69.5 | 25 |
| Left 2 | 1 | 18 | 18 | 18 | 52 | 52 | 52 | 34 |
| | 2 | 27 | 31 | 29 | 61 | 60 | 60.5 | 31.5 |
| Right 1 | 1 | 12 | 11 | 11.5 | 24 | 28 | 26 | 14.5 |
| | 2 | 14 | 13 | 13.5 | 27 | 32 | 29.5 | 16 |
| Right 3 | 1 | 22 | 22 | 22 | 72 | 71 | 71.5 | 49.5 |
| | 2 | 27 | 20 | 23.5 | 60 | 64 | 62 | 38.5 |
| Right 2 | 1 | 22 | 27 | 24.5 | 39 | 47 | 43 | 18.5 |
| | 2 | 32 | 37 | 34.5 | 51 | 58 | 54.5 | 20 |

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| | | |
|---|---|---|
| Name | 14 | M |
| Age | 56 | y |
| Height | 74.00 | in |
| Weight | 217.40 | lb |

| Detector | Scan | Fat 1 | Fat 2 | FatAvg | Tot 1 | Tot 2 | TotAvg | MuscAvg |
|---|---|---|---|---|---|---|---|---|
| Left 1 | 1 | 11 | 12 | 11.5 | 27 | 39 | 33 | 21.5 |
| | 2 | 12 | 17 | 14.5 | 31 | 37 | 34 | 19.5 |
| Left 3 | 1 | 15 | 15 | 15 | 45 | 49 | 47 | 32 |
| | 2 | 17 | 17 | 17 | 48 | 52 | 50 | 33 |
| Left 2 | 1 | 12 | 15 | 13.5 | 40 | 42 | 41 | 27.5 |
| | 2 | 17 | 19 | 18 | 40 | 44 | 42 | 24 |
| Right 1 | 1 | 9 | 9 | 9 | 28 | 28 | 28 | 19 |
| | 2 | 11 | 10 | 10.5 | 28 | 26 | 27 | 16.5 |
| Right 3 | 1 | 14 | 18 | 16 | 43 | 52 | 47.5 | 31.5 |
| | 2 | 16 | 13 | 14.5 | 46 | 53 | 49.5 | 35 |
| Right 2 | 1 | 17 | 18 | 17.5 | 42 | 44 | 43 | 25.5 |
| | 2 | 19 | 22 | 20.5 | 46 | 47 | 46.5 | 26 |

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| | | |
|---|---|---|
| Name | 15 | M |
| Age | 42 | y |
| Height | 72.00 | in |
| Weight | 205.40 | lb |

| Detector | Scan | Fat 1 | Fat 2 | FatAvg | Tot 1 | Tot 2 | TotAvg | MuscAvg |
|---|---|---|---|---|---|---|---|---|
| Left 1 | 1 | 12 | 11 | 11.5 | 27 | 28 | 27.5 | 16 |
| | 2 | 11 | 17 | 14 | 27 | 30 | 28.5 | 14.5 |
| Left 3 | 1 | 23 | 16 | 19.5 | 48 | 52 | 50 | 30.5 |
| | 2 | 21 | 18 | 19.5 | 54 | 54 | 54 | 34.5 |
| Left 2 | 1 | 16 | 17 | 16.5 | 36 | 42 | 39 | 22.5 |
| | 2 | 15 | 14 | 14.5 | 37 | 41 | 39 | 24.5 |
| Right 1 | 1 | 11 | 9 | 10 | 26 | 26 | 26 | 16 |
| | 2 | 10 | 12 | 11 | 26 | 27 | 26.5 | 15.5 |
| Right 3 | 1 | 17 | 16 | 16.5 | 40 | 44 | 42 | 25.5 |
| | 2 | 17 | 16 | 16.5 | 49 | 52 | 50.5 | 34 |
| Right 2 | 1 | 17 | 18 | 17.5 | 36 | 39 | 37.5 | 20 |
| | 2 | 15 | 19 | 17 | 38 | 42 | 40 | 23 |

| | | | |
|---|---|---|---|
| Name | 16 | M | |
| Age | 45 | y | Values are in (mm) |
| Height | 71.50 | in | |
| Weight | 213.80 | lb | |

| Detector | Scan | Fat 1 | Fat 2 | FatAvg | Tot | Tot 2 | TotAvg | MuscAvg |
|---|---|---|---|---|---|---|---|---|
| Left 1 | 1 | 7 | 8 | 7.5 | 27 | 27 | 27 | 19.5 |
| | 2 | 8 | 9 | 8.5 | 29 | 31 | 30 | 21.5 |
| Left 3 | 1 | 13 | 18 | 15.5 | 44 | 53 | 48.5 | 33 |
| | 2 | 15 | 17 | 16 | 57 | 52 | 54.5 | 38.5 |
| Left 2 | 1 | 14 | 12 | 13 | 37 | 40 | 38.5 | 25.5 |
| | 2 | 14 | 13 | 13.5 | 38 | 39 | 38.5 | 25 |
| Right 1 | 1 | 7 | 10 | 8.5 | 32 | 32 | 32 | 23.5 |
| | 2 | 12 | 14 | 13 | 34 | 40 | 37 | 24 |
| Right 3 | 1 | 10 | 7 | 8.5 | 48 | 51 | 49.5 | 41 |
| | 2 | 12 | 12 | 12 | 60 | 58 | 59 | 47 |
| Right 2 | 1 | 16 | 14 | 15 | 41 | 43 | 42 | 27 |
| | 2 | 18 | 16 | 17 | 44 | 44 | 44 | 27 |

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| | | | |
|---|---|---|---|
| Name | 17 | M | |
| Age | 45 | y | |
| Height | 72.00 | in | |
| Weight | 181.60 | lb | |

| Detector | Scan | Fat 1 | Fat 2 | FatAvg | Tot | Tot 2 | TotAvg | MuscAvg |
|---|---|---|---|---|---|---|---|---|
| Left 1 | 1 | 7 | 7 | 7 | 23 | 27 | 25 | 18 |
| | 2 | 11 | 14 | 12.5 | 29 | 32 | 30.5 | 18 |
| Left 3 | 1 | 15 | 17 | 16 | 47 | 44 | 45.5 | 29.5 |
| | 2 | 14 | 13 | 13.5 | 57 | 51 | 54 | 40.5 |
| Left 2 | 1 | 12 | 13 | 12.5 | 25 | 24 | 24.5 | 12 |
| | 2 | 18 | 15 | 16.5 | 40 | 42 | 41 | 24.5 |
| Right 1 | 1 | 7 | 7 | 7 | 25 | 26 | 25.5 | 18.5 |
| | 2 | 9 | 9 | 9 | 24 | 32 | 28 | 19 |
| Right 3 | 1 | 12 | 12 | 12 | 42 | 44 | 43 | 31 |
| | 2 | 14 | 12 | 13 | 48 | 45 | 46.5 | 33.5 |
| Right 2 | 1 | 12 | 10 | 11 | 37 | 37 | 37 | 26 |
| | 2 | 15 | 14 | 14.5 | 42 | 40 | 41 | 26.5 |

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| | | | |
|---|---|---|---|
| Name | 18 | M | |
| Age | 50 | y | |
| Height | 72.00 | in | |
| Weight | 176.10 | lb | |

| Detector | Scan | Fat 1 | Fat 2 | FatAvg | Tot | Tot 2 | TotAvg | MuscAvg |
|---|---|---|---|---|---|---|---|---|
| Left 1 | 1 | 5 | 5 | 5 | 23 | 25 | 24 | 19 |
| | 2 | 6 | 7 | 6.5 | 22 | 24 | 23 | 16.5 |
| Left 3 | 1 | 10 | 13 | 11.5 | 36 | 37 | 36.5 | 25 |
| | 2 | 11 | 7 | 9 | 41 | 39 | 40 | 31 |
| Left 2 | 1 | 8 | 7 | 7.5 | 27 | 30 | 28.5 | 21 |
| | 2 | 12 | 10 | 11 | 34 | 32 | 33 | 22 |
| Right 1 | 1 | 10 | 13 | 11.5 | 20 | 24 | 22 | 10.5 |
| | 2 | 7 | 8 | 7.5 | 22 | 27 | 24.5 | 17 |
| Right 3 | 1 | 7 | 11 | 9 | 35 | 40 | 37.5 | 28.5 |
| | 2 | 7 | 8 | 7.5 | 43 | 47 | 45 | 37.5 |
| Right 2 | 1 | 9 | 7 | 8 | 30 | 28 | 29 | 21 |
| | 2 | 11 | 10 | 10.5 | 32 | 30 | 31 | 20.5 |

| | | |
|---|---|---|
| Name | 19 | M |
| Age | 47 | y |
| Height | 71.50 | in |
| Weight | 213.60 | lb |

Values are in (mm)

| Detector | Scan | Fat 1 | Fat 2 | FatAvg | Tot | Tot 2 | TotAvg | MuscAvg |
|---|---|---|---|---|---|---|---|---|
| Left 1 | 1 | 10 | 11 | 10.5 | 32 | 33 | 32.5 | 22 |
| | 2 | 19 | 21 | 20 | 36 | 37 | 36.5 | 16.5 |
| Left 3 | 1 | 22 | 26 | 24 | 51 | 52 | 51.5 | 27.5 |
| | 2 | 20 | 16 | 18 | 60 | 61 | 60.5 | 42.5 |
| Left 2 | 1 | 12 | 14 | 13 | 25 | 28 | 26.5 | 13.5 |
| | 2 | 14 | 13 | 13.5 | 28 | 30 | 29 | 15.5 |
| Right 1 | 1 | 12 | 10 | 11 | 32 | 35 | 33.5 | 22.5 |
| | 2 | 12 | 16 | 14 | 30 | 37 | 33.5 | 19.5 |
| Right 3 | 1 | 15 | 14 | 14.5 | 60 | 57 | 58.5 | 44 |
| | 2 | 17 | 16 | 16.5 | 57 | 57 | 57 | 40.5 |
| Right 2 | 1 | 20 | 18 | 19 | 49 | 46 | 47.5 | 28.5 |
| | 2 | 22 | 18 | 20 | 53 | 50 | 51.5 | 31.5 |

| | | |
|---|---|---|
| Name | 20 | M |
| Age | 48 | y |
| Height | 70.25 | in |
| Weight | 174.80 | lb |

| Detector | Scan | Fat 1 | Fat 2 | FatAvg | Tot | Tot 2 | TotAvg | MuscAvg |
|---|---|---|---|---|---|---|---|---|
| Left 1 | 1 | 6 | 7 | 6.5 | 22 | 22 | 22 | 15.5 |
| | 2 | 8 | 9 | 8.5 | 24 | 25 | 24.5 | 16 |
| Left 3 | 1 | 10 | 12 | 11 | 51 | 49 | 50 | 39 |
| | 2 | 11 | 10 | 10.5 | 51 | 48 | 49.5 | 39 |
| Left 2 | 1 | 10 | 9 | 9.5 | 36 | 39 | 37.5 | 28 |
| | 2 | 11 | 11 | 11 | 42 | 42 | 42 | 31 |
| Right 1 | 1 | 10 | 13 | 11.5 | 27 | 33 | 30 | 18.5 |
| | 2 | 7 | 9 | 8 | 24 | 27 | 25.5 | 17.5 |
| Right 3 | 1 | 12 | 12 | 12 | 44 | 47 | 45.5 | 33.5 |
| | 2 | 12 | 12 | 12 | 44 | 45 | 44.5 | 32.5 |
| Right 2 | 1 | 11 | 11 | 11 | 37 | 38 | 37.5 | 26.5 |
| | 2 | 12 | 10 | 11 | 36 | 39 | 37.5 | 26.5 |

| | | |
|---|---|---|
| Name | 21 | M |
| Age | 46 | y |
| Height | 63.50 | in |
| Weight | 135.00 | lb |

| Detector | Scan | Fat 1 | Fat 2 | FatAvg | Tot | Tot 2 | TotAvg | MuscAvg |
|---|---|---|---|---|---|---|---|---|
| Left 1 | 1 | 10 | 9 | 9.5 | 23 | 25 | 24 | 14.5 |
| | 2 | 9 | 11 | 10 | 22 | 26 | 24 | 14 |
| Left 3 | 1 | 16 | 18 | 17 | 32 | 32 | 32 | 15 |
| | 2 | 14 | 15 | 14.5 | 37 | 38 | 37.5 | 23 |
| Left 2 | 1 | 11 | 9 | 10 | 27 | 26 | 26.5 | 16.5 |
| | 2 | 9 | 12 | 10.5 | 35 | 36 | 35.5 | 25 |
| Right 1 | 1 | 12 | 8 | 10 | 24 | 25 | 24.5 | 14.5 |
| | 2 | 11 | 12 | 11.5 | 23 | 27 | 25 | 13.5 |
| Right 3 | 1 | 11 | 12 | 11.5 | 33 | 37 | 35 | 23.5 |
| | 2 | 11 | 17 | 14 | 41 | 46 | 43.5 | 29.5 |
| Right 2 | 1 | 15 | 16 | 15.5 | 31 | 31 | 31 | 15.5 |
| | 2 | 17 | 24 | 20.5 | 34 | 40 | 37 | 16.5 |

| | | |
|---|---|---|
| Name | 22 | M |
| Age | 33 | y |
| Height | 72.50 | in |
| Weight | 243.40 | lb |

Values are in (mm)

| Detector | Scan | Fat 1 | Fat 2 | FatAvg | Tot | Tot 2 | TotAvg | MuscAvg |
|---|---|---|---|---|---|---|---|---|
| Left 1 | 1 | 11 | 9 | 10 | 28 | 32 | 30 | 20 |
| | 2 | 12 | 10 | 11 | 31 | 34 | 32.5 | 21.5 |
| Left 3 | 1 | 22 | 25 | 23.5 | 50 | 54 | 52 | 28.5 |
| | 2 | 17 | 17 | 17 | 55 | 57 | 56 | 39 |
| Left 2 | 1 | 15 | 11 | 13 | 41 | 44 | 42.5 | 29.5 |
| | 2 | 20 | 21 | 20.5 | 41 | 45 | 43 | 22.5 |
| Right 1 | 1 | 13 | 13 | 13 | 29 | 35 | 32 | 19 |
| | 2 | 11 | 9 | 10 | 30 | 35 | 32.5 | 22.5 |
| Right 3 | 1 | 20 | 26 | 23 | 50 | 58 | 54 | 31 |
| | 2 | 19 | 18 | 18.5 | 57 | 61 | 59 | 40.5 |
| Right 2 | 1 | 12 | 11 | 11.5 | 41 | 43 | 42 | 30.5 |
| | 2 | 13 | 11 | 12 | 45 | 47 | 46 | 34 |

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| | | |
|---|---|---|
| Name | 23 | M |
| Age | 44 | y |
| Height | 72.00 | in |
| Weight | 199.80 | lb |

| Detector | Scan | Fat 1 | Fat 2 | FatAvg | Tot | Tot 2 | TotAvg | MuscAvg |
|---|---|---|---|---|---|---|---|---|
| Left 1 | 1 | 8 | 7 | 7.5 | 28 | 25 | 26.5 | 19 |
| | 2 | 8 | 9 | 8.5 | 25 | 26 | 25.5 | 17 |
| Left 3 | 1 | 12 | 14 | 13 | 44 | 39 | 41.5 | 28.5 |
| | 2 | 12 | 12 | 12 | 48 | 43 | 45.5 | 33.5 |
| Left 2 | 1 | 8 | 7 | 7.5 | 32 | 31 | 31.5 | 24 |
| | 2 | 12 | 11 | 11.5 | 35 | 36 | 35.5 | 24 |
| Right 1 | 1 | 7 | 8 | 7.5 | 27 | 28 | 27.5 | 20 |
| | 2 | 7 | 9 | 8 | 27 | 29 | 28 | 20 |
| Right 3 | 1 | 10 | 13 | 11.5 | 42 | 52 | 47 | 35.5 |
| | 2 | 10 | 10 | 10 | 42 | 46 | 44 | 34 |
| Right 2 | 1 | 10 | 11 | 10.5 | 30 | 34 | 32 | 21.5 |
| | 2 | 12 | 13 | 12.5 | 39 | 39 | 39 | 26.5 |

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| | | |
|---|---|---|
| Name | 24 | M |
| Age | 45 | y |
| Height | 71.75 | in |
| Weight | 181.80 | lb |

| Detector | Scan | Fat 1 | Fat 2 | FatAvg | Tot | Tot 2 | TotAvg | MuscAvg |
|---|---|---|---|---|---|---|---|---|
| Left 1 | 1 | 5 | 8 | 6.5 | 22 | 26 | 24 | 17.5 |
| | 2 | 7 | 8 | 7.5 | 27 | 30 | 28.5 | 21 |
| Left 3 | 1 | 12 | 9 | 10.5 | 44 | 37 | 40.5 | 30 |
| | 2 | 12 | 13 | 12.5 | 41 | 44 | 42.5 | 30 |
| Left 2 | 1 | 9 | 7 | 8 | 35 | 35 | 35 | 27 |
| | 2 | 8 | 9 | 8.5 | 34 | 31 | 32.5 | 24 |
| Right 1 | 1 | 6 | 7 | 6.5 | 27 | 24 | 25.5 | 19 |
| | 2 | 5 | 7 | 6 | 24 | 26 | 25 | 19 |
| Right 3 | 1 | 10 | 11 | 10.5 | 39 | 42 | 40.5 | 30 |
| | 2 | 12 | 14 | 13 | 47 | 52 | 49.5 | 36.5 |
| Right 2 | 1 | 11 | 11 | 11 | 29 | 31 | 30 | 19 |
| | 2 | 8 | 12 | 10 | 32 | 31 | 31.5 | 21.5 |

| | | |
|---|---|---|
| Name | 25 | M |
| Age | 62 | y |
| Height | 72.00 | in |
| Weight | 197.40 | lb |

Values are in (mm)

| Detector | Scan | Fat 1 | Fat 2 | FatAvg | Tot | Tot 2 | TotAvg | MuscAvg |
|---|---|---|---|---|---|---|---|---|
| Left 1 | 1 | 7 | 7 | 7 | 25 | 25 | 25 | 18 |
| | 2 | 9 | 11 | 10 | 29 | 28 | 28.5 | 18.5 |
| Left 3 | 1 | 13 | 11 | 12 | 39 | 43 | 41 | 29 |
| | 2 | 12 | 13 | 12.5 | 48 | 47 | 47.5 | 35 |
| Left 2 | 1 | 8 | 10 | 9 | 42 | 41 | 41.5 | 32.5 |
| | 2 | 12 | 9 | 10.5 | 36 | 37 | 36.5 | 26 |
| Right 1 | 1 | 7 | 7 | 7 | 29 | 27 | 28 | 21 |
| | 2 | 10 | 9 | 9.5 | 29 | 27 | 28 | 18.5 |
| Right 3 | 1 | 12 | 14 | 13 | 36 | 39 | 37.5 | 24.5 |
| | 2 | 10 | 12 | 11 | 38 | 42 | 40 | 29 |
| Right 2 | 1 | 10 | 8 | 9 | 33 | 34 | 33.5 | 24.5 |
| | 2 | 12 | 10 | 11 | 32 | 34 | 33 | 22 |

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| | | |
|---|---|---|
| Name | 26 | M |
| Age | 32 | y |
| Height | 72.00 | in |
| Weight | 217.00 | lb |

| Detector | Scan | Fat 1 | Fat 2 | FatAvg | Tot | Tot 2 | TotAvg | MuscAvg |
|---|---|---|---|---|---|---|---|---|
| Left 1 | 1 | 9 | 10 | 9.5 | 27 | 32 | 29.5 | 20 |
| | 2 | 11 | 10 | 10.5 | 28 | 30 | 29 | 18.5 |
| Left 3 | 1 | 12 | 11 | 11.5 | 50 | 58 | 54 | 42.5 |
| | 2 | 12 | 14 | 13 | 52 | 61 | 56.5 | 43.5 |
| Left 2 | 1 | 11 | 10 | 10.5 | 37 | 40 | 38.5 | 28 |
| | 2 | 12 | 13 | 12.5 | 42 | 45 | 43.5 | 31 |
| Right 1 | 1 | 9 | 9 | 9 | 28 | 30 | 29 | 20 |
| | 2 | 9 | 7 | 8 | 25 | 28 | 26.5 | 18.5 |
| Right 3 | 1 | 12 | 12 | 12 | 40 | 43 | 41.5 | 29.5 |
| | 2 | 12 | 14 | 13 | 48 | 54 | 51 | 38 |
| Right 2 | 1 | 12 | 12 | 12 | 37 | 37 | 37 | 25 |
| | 2 | 12 | 11 | 11.5 | 40 | 43 | 41.5 | 30 |

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| | | |
|---|---|---|
| Name | 27 | M |
| Age | 51 | y |
| Height | 67.00 | in |
| Weight | 149.20 | lb |

| Detector | Scan | Fat 1 | Fat 2 | FatAvg | Tot | Tot 2 | TotAvg | MuscAvg |
|---|---|---|---|---|---|---|---|---|
| Left 1 | 1 | 7 | 7 | 7 | 22 | 26 | 24 | 17 |
| | 2 | 8 | 10 | 9 | 25 | 27 | 26 | 17 |
| Left 3 | 1 | 12 | 12 | 12 | 46 | 40 | 43 | 31 |
| | 2 | 11 | 10 | 10.5 | 36 | 36 | 36 | 25.5 |
| Left 2 | 1 | 8 | 9 | 8.5 | 20 | 17 | 18.5 | 10 |
| | 2 | 12 | 11 | 11.5 | 32 | 29 | 30.5 | 19 |
| Right 1 | 1 | 7 | 5 | 6 | 24 | 27 | 25.5 | 19.5 |
| | 2 | 9 | 11 | 10 | 23 | 27 | 25 | 15 |
| Right 3 | 1 | 10 | 9 | 9.5 | 35 | 37 | 36 | 26.5 |
| | 2 | 9 | 11 | 10 | 39 | 39 | 39 | 29 |
| Right 2 | 1 | 9 | 8 | 8.5 | 32 | 28 | 30 | 21.5 |
| | 2 | 13 | 10 | 11.5 | 37 | 35 | 36 | 24.5 |

| | | |
|---|---|---|
| Name | 28 | M |
| Age | 29 | y |
| Height | 72.00 | in |
| Weight | 238.80 | lb |

Values are in (mm)

| Detector | Scan | Fat 1 | Fat 2 | FatAvg | Tot | Tot 2 | TotAvg | MuscAvg |
|---|---|---|---|---|---|---|---|---|
| Left 1 | 1 | 12 | 14 | 13 | 32 | 31 | 31.5 | 18.5 |
| | 2 | 14 | 17 | 15.5 | 33 | 34 | 33.5 | 18 |
| Left 3 | 1 | 10 | 12 | 11 | 53 | 53 | 53 | 42 |
| | 2 | 11 | 11 | 11 | 59 | 57 | 58 | 47 |
| Left 2 | 1 | 13 | 13 | 13 | 36 | 35 | 35.5 | 22.5 |
| | 2 | 14 | 14 | 14 | 42 | 42 | 42 | 28 |
| Right 1 | 1 | 10 | 10 | 10 | 32 | 32 | 32 | 22 |
| | 2 | 11 | 12 | 11.5 | 40 | 42 | 41 | 29.5 |
| Right 3 | 1 | 22 | 22 | 22 | 50 | 50 | 50 | 28 |
| | 2 | 17 | 15 | 16 | 53 | 56 | 54.5 | 38.5 |
| Right 2 | 1 | 14 | 12 | 13 | 43 | 45 | 44 | 31 |
| | 2 | 13 | 13 | 13 | 41 | 41 | 41 | 28 |

| | | |
|---|---|---|
| Name | 29 | M |
| Age | 34 | y |
| Height | 71.00 | in |
| Weight | 262.80 | lb |

| Detector | Scan | Fat 1 | Fat 2 | FatAvg | Tot | Tot 2 | TotAvg | MuscAvg |
|---|---|---|---|---|---|---|---|---|
| Left 1 | 1 | 9 | 10 | 9.5 | 33 | 32 | 32.5 | 23 |
| | 2 | 14 | 12 | 13 | 37 | 38 | 37.5 | 24.5 |
| Left 3 | 1 | 13 | 17 | 15 | 58 | 59 | 58.5 | 43.5 |
| | 2 | 15 | 17 | 16 | 65 | 61 | 63 | 47 |
| Left 2 | 1 | 17 | 17 | 17 | 32 | 33 | 32.5 | 15.5 |
| | 2 | 17 | 18 | 17.5 | 36 | 37 | 36.5 | 19 |
| Right 1 | 1 | 12 | 12 | 12 | 35 | 35 | 35 | 23 |
| | 2 | 10 | 12 | 11 | 31 | 32 | 31.5 | 20.5 |
| Right 3 | 1 | 12 | 14 | 13 | 48 | 56 | 52 | 39 |
| | 2 | 15 | 17 | 16 | 60 | 64 | 62 | 46 |
| Right 2 | 1 | 12 | 12 | 12 | 44 | 49 | 46.5 | 34.5 |
| | 2 | 13 | 13 | 13 | 50 | 56 | 53 | 40 |

| | | |
|---|---|---|
| Name | 30 | M |
| Age | 38 | y |
| Height | 72.00 | in |
| Weight | 191.40 | lb |

| Detector | Scan | Fat 1 | Fat 2 | FatAvg | Tot | Tot 2 | TotAvg | MuscAvg |
|---|---|---|---|---|---|---|---|---|
| Left 1 | 1 | 6 | 7 | 6.5 | 20 | 24 | 22 | 15.5 |
| | 2 | 7 | 7 | 7 | 22 | 24 | 23 | 16 |
| Left 3 | 1 | 11 | 12 | 11.5 | 42 | 38 | 40 | 28.5 |
| | 2 | 10 | 12 | 11 | 42 | 44 | 43 | 32 |
| Left 2 | 1 | 9 | 7 | 8 | 27 | 27 | 27 | 19 |
| | 2 | 9 | 9 | 9 | 24 | 24 | 24 | 15 |
| Right 1 | 1 | 6 | 7 | 6.5 | 27 | 26 | 26.5 | 20 |
| | 2 | 6 | 8 | 7 | 26 | 29 | 27.5 | 20.5 |
| Right 3 | 1 | 11 | 12 | 11.5 | 40 | 42 | 41 | 29.5 |
| | 2 | 9 | 11 | 10 | 47 | 48 | 47.5 | 37.5 |
| Right 2 | 1 | 7 | 6 | 6.5 | 31 | 31 | 31 | 24.5 |
| | 2 | 7 | 7 | 7 | 35 | 33 | 34 | 27 |

| | | |
|---|---|---|
| Name | 31 | M |
| Age | 32 | y |
| Height | 72.75 | in |
| Weight | 191.20 | lb |

Values are in (mm)

| Detector | Scan | Fat 1 | Fat 2 | FatAvg | Tot | Tot 2 | TotAvg | MuscAvg |
|---|---|---|---|---|---|---|---|---|
| Left 1 | 1 | 7 | 7 | 7 | 23 | 26 | 24.5 | 17.5 |
| | 2 | 10 | 12 | 11 | 27 | 32 | 29.5 | 18.5 |
| Left 3 | 1 | 14 | 15 | 14.5 | 50 | 52 | 51 | 36.5 |
| | 2 | 13 | 16 | 14.5 | 53 | 52 | 52.5 | 38 |
| Left 2 | 1 | 12 | 13 | 12.5 | 34 | 36 | 35 | 22.5 |
| | 2 | 14 | 12 | 13 | 40 | 40 | 40 | 27 |
| Right 1 | 1 | 6 | 6 | 6 | 23 | 25 | 24 | 18 |
| | 2 | 6 | 7 | 6.5 | 23 | 27 | 25 | 18.5 |
| Right 3 | 1 | 9 | 10 | 9.5 | 39 | 41 | 40 | 30.5 |
| | 2 | 10 | 11 | 10.5 | 47 | 50 | 48.5 | 38 |
| Right 2 | 1 | 11 | 11 | 11 | 31 | 34 | 32.5 | 21.5 |
| | 2 | 10 | 12 | 11 | 36 | 38 | 37 | 26 |

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| | | |
|---|---|---|
| Name | 32 | M |
| Age | 43 | y |
| Height | 71.00 | in |
| Weight | 219.80 | lb |

| Detector | Scan | Fat 1 | Fat 2 | FatAvg | Tot | Tot 2 | TotAvg | MuscAvg |
|---|---|---|---|---|---|---|---|---|
| Left 1 | 1 | 7 | 7 | 7 | 28 | 27 | 27.5 | 20.5 |
| | 2 | 7 | 7 | 7 | 28 | 24 | 26 | 19 |
| Left 3 | 1 | 8 | 7 | 7.5 | 46 | 52 | 49 | 41.5 |
| | 2 | 14 | 13 | 13.5 | 55 | 59 | 57 | 43.5 |
| Left 2 | 1 | 12 | 11 | 11.5 | 42 | 42 | 42 | 30.5 |
| | 2 | 13 | 12 | 12.5 | 44 | 46 | 45 | 32.5 |
| Right 1 | 1 | 7 | 8 | 7.5 | 29 | 27 | 28 | 20.5 |
| | 2 | 8 | 9 | 8.5 | 29 | 34 | 31.5 | 23 |
| Right 3 | 1 | 11 | 13 | 12 | 50 | 57 | 53.5 | 41.5 |
| | 2 | 12 | 13 | 12.5 | 52 | 61 | 56.5 | 44 |
| Right 2 | 1 | 10 | 10 | 10 | 38 | 46 | 42 | 32 |
| | 2 | 12 | 10 | 11 | 43 | 47 | 45 | 34 |

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| | | |
|---|---|---|
| Name | 33 | M |
| Age | 58 | y |
| Height | 74.00 | in |
| Weight | 209.60 | lb |

| Detector | Scan | Fat 1 | Fat 2 | FatAvg | Tot | Tot 2 | TotAvg | MuscAvg |
|---|---|---|---|---|---|---|---|---|
| Left 1 | 1 | 7 | 9 | 8 | 27 | 27 | 27 | 19 |
| | 2 | 12 | 11 | 11.5 | 35 | 38 | 36.5 | 25 |
| Left 3 | 1 | 12 | 12 | 12 | 47 | 51 | 49 | 37 |
| | 2 | 16 | 18 | 17 | 52 | 51 | 51.5 | 34.5 |
| Left 2 | 1 | 9 | 11 | 10 | 23 | 22 | 22.5 | 12.5 |
| | 2 | 14 | 13 | 13.5 | 27 | 27 | 27 | 13.5 |
| Right 1 | 1 | 7 | 9 | 8 | 25 | 29 | 27 | 19 |
| | 2 | 8 | 10 | 9 | 24 | 29 | 26.5 | 17.5 |
| Right 3 | 1 | 17 | 18 | 17.5 | 47 | 49 | 48 | 30.5 |
| | 2 | 13 | 14 | 13.5 | 47 | 49 | 48 | 34.5 |
| Right 2 | 1 | 12 | 11 | 11.5 | 37 | 39 | 38 | 26.5 |
| | 2 | 15 | 12 | 13.5 | 43 | 43 | 43 | 29.5 |

# APPENDIX B

## FEMALE SUBJECT ULTRASOUND DATA

| | | |
|---|---|---|
| Name | 1 | F |
| Age | 37 | y |
| Height | 62.5 | in |
| Weight | 140.6 | lb |

Values are in (mm)

| Detector | Scan | Fat 1 | Fat 2 | FatAvg | Tot 1 | Tot 2 | TotAvg | MuscAvg |
|---|---|---|---|---|---|---|---|---|
| Left 1 | 1 | 5 | 5 | 5 | 17 | 17 | 17 | 12 |
| | 2 | 6 | 7 | 6.5 | 18 | 19 | 18.5 | 12 |
| Left 3 | 1 | 16 | 34 | 25 | 36 | 47 | 41.5 | 16.5 |
| | 2 | 28 | 38 | 33 | 40 | 46 | 43 | 10 |
| Left 2 | 1 | 20 | 32 | 26 | 29 | 43 | 36 | 10 |
| | 2 | 18 | 27 | 22.5 | 27 | 37 | 32 | 9.5 |
| Right 1 | 1 | 6 | 11 | 8.5 | 20 | 26 | 23 | 14.5 |
| | 2 | 7 | 12 | 9.5 | 20 | 25 | 22.5 | 13 |
| Right 3 | 1 | 27 | 36 | 31.5 | 39 | 50 | 44.5 | 13 |
| | 2 | 26 | 39 | 32.5 | 38 | 48 | 43 | 10.5 |
| Right 2 | 1 | 27 | 37 | 32 | 44 | 53 | 48.5 | 16.5 |
| | 2 | 38 | 47 | 42.5 | 52 | 61 | 56.5 | 14 |

| | | |
|---|---|---|
| Name | 2 | F |
| Age | 46 | y |
| Height | 66.25 | in |
| Weight | 149.4 | lb |

| Detector | Scan | Fat 1 | Fat 2 | FatAvg | Tot 1 | Tot 2 | TotAvg | MuscAvg |
|---|---|---|---|---|---|---|---|---|
| Left 1 | 1 | 9 | 9 | 9 | 19 | 22 | 20.5 | 11.5 |
| | 2 | 11 | 13 | 12 | 21 | 23 | 22 | 10 |
| Left 3 | 1 | 34 | 42 | 38 | 42 | 56 | 49 | 11 |
| | 2 | 34 | 42 | 38 | 41 | 54 | 47.5 | 9.5 |
| Left 2 | 1 | 20 | 33 | 26.5 | 32 | 47 | 39.5 | 13 |
| | 2 | 27 | 33 | 30 | 37 | 50 | 43.5 | 13.5 |
| Right 1 | 1 | 7 | 9 | 8 | 17 | 21 | 19 | 11 |
| | 2 | 13 | 21 | 17 | 22 | 30 | 26 | 9 |
| Right 3 | 1 | 32 | 44 | 38 | 41 | 53 | 47 | 9 |
| | 2 | 32 | 45 | 38.5 | 42 | 56 | 49 | 10.5 |
| Right 2 | 1 | 26 | 29 | 27.5 | 46 | 53 | 49.5 | 22 |
| | 2 | 37 | 47 | 42 | 49 | 63 | 56 | 14 |

| | | |
|---|---|---|
| Name | 3 | F |
| Age | 43 | y |
| Height | 63 | in |
| Weight | 100 | lb |

| Detector | Scan | Fat 1 | Fat 2 | FatAvg | Tot 1 | Tot 2 | TotAvg | MuscAvg |
|---|---|---|---|---|---|---|---|---|
| Left 1 | 1 | 6 | 7 | 6.5 | 12 | 14 | 13 | 6.5 |
| | 2 | 5 | 8 | 6.5 | 14 | 15 | 14.5 | 8 |
| Left 3 | 1 | 16 | 22 | 19 | 40 | 44 | 42 | 23 |
| | 2 | 17 | 20 | 18.5 | 30 | 27 | 28.5 | 10 |
| Left 2 | 1 | 11 | 17 | 14 | 15 | 22 | 18.5 | 4.5 |
| | 2 | 8 | 12 | 10 | 16 | 21 | 18.5 | 8.5 |
| Right 1 | 1 | 7 | 7 | 7 | 18 | 14 | 16 | 9 |
| | 2 | 7 | 8 | 7.5 | 12 | 15 | 13.5 | 6 |
| Right 3 | 1 | 15 | 13 | 14 | 23 | 24 | 23.5 | 9.5 |
| | 2 | 21 | 17 | 19 | 27 | 24 | 25.5 | 6.5 |
| Right 2 | 1 | 11 | 17 | 14 | 17 | 22 | 19.5 | 5.5 |
| | 2 | 10 | 18 | 14 | 16 | 23 | 20 | 6 |

| | | |
|---|---|---|
| Name | 4 | F |
| Age | 43 | y |
| Height | 57.25 | in |
| Weight | 86.6 | lb |

Values are in (mm)

| Detector | Scan | Fat 1 | Fat 2 | FatAvg | Tot 1 | Tot 2 | TotAvg | MuscAvg |
|---|---|---|---|---|---|---|---|---|
| Left 1 | 1 | 5 | 7 | 6 | 12 | 14 | 13 | 7 |
| | 2 | 10 | 12 | 11 | 16 | 19 | 17.5 | 6.5 |
| Left 3 | 1 | 20 | 19 | 19.5 | 28 | 26 | 27 | 7.5 |
| | 2 | 15 | 20 | 17.5 | 24 | 30 | 27 | 9.5 |
| Left 2 | 1 | 17 | 20 | 18.5 | 26 | 27 | 26.5 | 8 |
| | 2 | 14 | 16 | 15 | 21 | 26 | 23.5 | 8.5 |
| Right 1 | 1 | 6 | 9 | 7.5 | 15 | 17 | 16 | 8.5 |
| | 2 | 10 | 9 | 9.5 | 21 | 24 | 22.5 | 13 |
| Right 3 | 1 | 17 | 16 | 16.5 | 27 | 25 | 26 | 9.5 |
| | 2 | 19 | 23 | 21 | 27 | 32 | 29.5 | 8.5 |
| Right 2 | 1 | 16 | 17 | 16.5 | 24 | 22 | 23 | 6.5 |
| | 2 | 17 | 17 | 17 | 27 | 26 | 26.5 | 9.5 |

| | | |
|---|---|---|
| Name | 5 | F |
| Age | 33 | y |
| Height | 61 | in |
| Weight | 219.8 | lb |

| Detector | Scan | Fat 1 | Fat 2 | FatAvg | Tot 1 | Tot 2 | TotAvg | MuscAvg |
|---|---|---|---|---|---|---|---|---|
| Left 1 | 1 | 7 | 21 | 14 | 27 | 34 | 30.5 | 16.5 |
| | 2 | 18 | 25 | 21.5 | 35 | 47 | 41 | 19.5 |
| Left 3 | 1 | 82 | 82 | 82 | 102 | 102 | 102 | 20 |
| | 2 | 48 | 61 | 54.5 | 72 | 79 | 75.5 | 21 |
| Left 2 | 1 | 44 | 48 | 46 | 61 | 63 | 62 | 16 |
| | 2 | 36 | 57 | 46.5 | 60 | 77 | 68.5 | 22 |
| Right 1 | 1 | 21 | 23 | 22 | 32 | 45 | 38.5 | 16.5 |
| | 2 | 17 | 28 | 22.5 | 32 | 49 | 40.5 | 18 |
| Right 3 | 1 | 44 | 43 | 43.5 | 56 | 70 | 63 | 19.5 |
| | 2 | 45 | 46 | 45.5 | 59 | 66 | 62.5 | 17 |
| Right 2 | 1 | 11 | 19 | 15 | 31 | 35 | 33 | 18 |
| | 2 | 34 | 33 | 33.5 | 51 | 62 | 56.5 | 23 |

| | | |
|---|---|---|
| Name | 6 | F |
| Age | 48 | y |
| Height | 61 | in |
| Weight | 129.6 | lb |

| Detector | Scan | Fat 1 | Fat 2 | FatAvg | Tot 1 | Tot 2 | TotAvg | MuscAvg |
|---|---|---|---|---|---|---|---|---|
| Left 1 | 1 | 7 | 15 | 11 | 16 | 21 | 18.5 | 7.5 |
| | 2 | 17 | 21 | 19 | 25 | 33 | 29 | 10 |
| Left 3 | 1 | 39 | 43 | 41 | 54 | 65 | 59.5 | 18.5 |
| | 2 | 44 | 52 | 48 | 57 | 66 | 61.5 | 13.5 |
| Left 2 | 1 | 27 | 32 | 29.5 | 32 | 44 | 38 | 8.5 |
| | 2 | 28 | 33 | 30.5 | 37 | 42 | 39.5 | 9 |
| Right 1 | 1 | 11 | 15 | 13 | 18 | 22 | 20 | 7 |
| | 2 | 14 | 21 | 17.5 | 25 | 32 | 28.5 | 11 |
| Right 3 | 1 | 30 | 35 | 32.5 | 42 | 48 | 45 | 12.5 |
| | 2 | 33 | 42 | 37.5 | 46 | 57 | 51.5 | 14 |
| Right 2 | 1 | 33 | 44 | 38.5 | 45 | 57 | 51 | 12.5 |
| | 2 | 32 | 39 | 35.5 | 44 | 57 | 50.5 | 15 |

| | | | |
|---|---|---|---|
| Name | 7 | F | |
| Age | 34 | y | Values are in (mm) |
| Height | 64 | in | |
| Weight | 146.4 | lb | |

| Detector | Scan | Fat 1 | Fat 2 | FatAvg | Tot 1 | Tot 2 | TotAvg | MuscAvg |
|---|---|---|---|---|---|---|---|---|
| Left 1 | 1 | 9 | 11 | 10 | 21 | 23 | 22 | 12 |
| | 2 | 13 | 17 | 15 | 25 | 26 | 25.5 | 10.5 |
| Left 3 | 1 | 21 | 27 | 24 | 37 | 38 | 37.5 | 13.5 |
| | 2 | 25 | 31 | 28 | 38 | 40 | 39 | 11 |
| Left 2 | 1 | 19 | 22 | 20.5 | 32 | 37 | 34.5 | 14 |
| | 2 | 22 | 26 | 24 | 36 | 37 | 36.5 | 12.5 |
| Right 1 | 1 | 9 | 13 | 11 | 22 | 23 | 22.5 | 11.5 |
| | 2 | 12 | 17 | 14.5 | 26 | 29 | 27.5 | 13 |
| Right 3 | 1 | 26 | 26 | 26 | 39 | 39 | 39 | 13 |
| | 2 | 27 | 27 | 27 | 40 | 39 | 39.5 | 12.5 |
| Right 2 | 1 | 24 | 26 | 25 | 35 | 37 | 36 | 11 |
| | 2 | 28 | 37 | 32.5 | 40 | 42 | 41 | 8.5 |

| | | | |
|---|---|---|---|
| Name | 8 | F | |
| Age | 24 | y | |
| Height | 66.5 | in | |
| Weight | 137.2 | lb | |

| Detector | Scan | Fat 1 | Fat 2 | FatAvg | Tot 1 | Tot 2 | TotAvg | MuscAvg |
|---|---|---|---|---|---|---|---|---|
| Left 1 | 1 | 11 | 11 | 11 | 22 | 22 | 22 | 11 |
| | 2 | 10 | 11 | 10.5 | 21 | 23 | 22 | 11.5 |
| Left 3 | 1 | 17 | 27 | 22 | 39 | 49 | 44 | 22 |
| | 2 | 23 | 37 | 30 | 42 | 51 | 46.5 | 16.5 |
| Left 2 | 1 | 17 | 22 | 19.5 | 23 | 31 | 27 | 7.5 |
| | 2 | 22 | 21 | 21.5 | 33 | 32 | 32.5 | 11 |
| Right 1 | 1 | 10 | 15 | 12.5 | 21 | 27 | 24 | 11.5 |
| | 2 | 9 | 14 | 11.5 | 22 | 32 | 27 | 15.5 |
| Right 3 | 1 | 31 | 31 | 31 | 45 | 47 | 46 | 15 |
| | 2 | 30 | 32 | 31 | 45 | 43 | 44 | 13 |
| Right 2 | 1 | 32 | 39 | 35.5 | 40 | 47 | 43.5 | 8 |
| | 2 | 37 | 47 | 42 | 48 | 54 | 51 | 9 |

| | | | |
|---|---|---|---|
| Name | 9 | F | |
| Age | 26 | y | |
| Height | 63 | in | |
| Weight | 128.2 | lb | |

| Detector | Scan | Fat 1 | Fat 2 | FatAvg | Tot 1 | Tot 2 | TotAvg | MuscAvg |
|---|---|---|---|---|---|---|---|---|
| Left 1 | 1 | 5 | 9 | 7 | 16 | 20 | 18 | 11 |
| | 2 | 13 | 17 | 15 | 28 | 36 | 32 | 17 |
| Left 3 | 1 | 34 | 37 | 35.5 | 47 | 55 | 51 | 15.5 |
| | 2 | 26 | 34 | 30 | 46 | 47 | 46.5 | 16.5 |
| Left 2 | 1 | 27 | 28 | 27.5 | 34 | 37 | 35.5 | 8 |
| | 2 | 36 | 37 | 36.5 | 44 | 43 | 43.5 | 7 |
| Right 1 | 1 | 10 | 12 | 11 | 19 | 26 | 22.5 | 11.5 |
| | 2 | 14 | 14 | 14 | 28 | 36 | 32 | 18 |
| Right 3 | 1 | 37 | 38 | 37.5 | 47 | 45 | 46 | 8.5 |
| | 2 | 36 | 32 | 34 | 50 | 45 | 47.5 | 13.5 |
| Right 2 | 1 | 19 | 23 | 21 | 33 | 37 | 35 | 14 |
| | 2 | 32 | 31 | 31.5 | 42 | 42 | 42 | 10.5 |

| | | |
|---|---|---|
| Name | 10 | F |
| Age | 41 | y |
| Height | 68 | in |
| Weight | 173.6 | lb |

Values are in (mm)

| Detector | Scan | Fat 1 | Fat 2 | FatAvg | Tot 1 | Tot 2 | TotAvg | MuscAvg |
|---|---|---|---|---|---|---|---|---|
| Left 1 | 1 | 8 | 12 | 10 | 21 | 23 | 22 | 12 |
| | 2 | 13 | 14 | 13.5 | 27 | 27 | 27 | 13.5 |
| Left 3 | 1 | 22 | 32 | 27 | 44 | 52 | 48 | 21 |
| | 2 | 22 | 37 | 29.5 | 50 | 54 | 52 | 22.5 |
| Left 2 | 1 | 21 | 24 | 22.5 | 35 | 37 | 36 | 13.5 |
| | 2 | 32 | 34 | 33 | 41 | 42 | 41.5 | 8.5 |
| Right 1 | 1 | 7 | 12 | 9.5 | 21 | 25 | 23 | 13.5 |
| | 2 | 13 | 16 | 14.5 | 29 | 37 | 33 | 18.5 |
| Right 3 | 1 | 34 | 38 | 36 | 52 | 53 | 52.5 | 16.5 |
| | 2 | 35 | 35 | 35 | 53 | 50 | 51.5 | 16.5 |
| Right 2 | 1 | 27 | 31 | 29 | 37 | 42 | 39.5 | 10.5 |
| | 2 | 42 | 55 | 48.5 | 51 | 60 | 55.5 | 7 |

| | | |
|---|---|---|
| Name | 11 | F |
| Age | 42 | y |
| Height | 64.75 | in |
| Weight | 138.6 | lb |

| Detector | Scan | Fat 1 | Fat 2 | FatAvg | Tot 1 | Tot 2 | TotAvg | MuscAvg |
|---|---|---|---|---|---|---|---|---|
| Left 1 | 1 | 7 | 8 | 7.5 | 17 | 17 | 17 | 9.5 |
| | 2 | 7 | 8 | 7.5 | 17 | 26 | 21.5 | 14 |
| Left 3 | 1 | 21 | 36 | 28.5 | 38 | 56 | 47 | 18.5 |
| | 2 | 26 | 37 | 31.5 | 43 | 50 | 46.5 | 15 |
| Left 2 | 1 | 22 | 27 | 24.5 | 36 | 37 | 36.5 | 12 |
| | 2 | 24 | 37 | 30.5 | 39 | 50 | 44.5 | 14 |
| Right 1 | 1 | 9 | 17 | 13 | 17 | 29 | 23 | 10 |
| | 2 | 8 | 17 | 12.5 | 17 | 27 | 22 | 9.5 |
| Right 3 | 1 | 37 | 40 | 38.5 | 49 | 58 | 53.5 | 15 |
| | 2 | 19 | 21 | 20 | 38 | 44 | 41 | 21 |
| Right 2 | 1 | 28 | 40 | 34 | 40 | 53 | 46.5 | 12.5 |
| | 2 | 36 | 43 | 39.5 | 57 | 63 | 60 | 20.5 |

| | | |
|---|---|---|
| Name | 12 | F |
| Age | 48 | y |
| Height | 64 | in |
| Weight | 125 | lb |

| Detector | Scan | Fat 1 | Fat 2 | FatAvg | Tot 1 | Tot 2 | TotAvg | MuscAvg |
|---|---|---|---|---|---|---|---|---|
| Left 1 | 1 | 8 | 8 | 8 | 17 | 18 | 17.5 | 9.5 |
| | 2 | 9 | 10 | 9.5 | 20 | 20 | 20 | 10.5 |
| Left 3 | 1 | 24 | 30 | 27 | 31 | 42 | 36.5 | 9.5 |
| | 2 | 22 | 25 | 23.5 | 30 | 37 | 33.5 | 10 |
| Left 2 | 1 | 17 | 24 | 20.5 | 29 | 34 | 31.5 | 11 |
| | 2 | 17 | 17 | 17 | 26 | 37 | 31.5 | 14.5 |
| Right 1 | 1 | 7 | 12 | 9.5 | 15 | 18 | 16.5 | 7 |
| | 2 | 7 | 11 | 9 | 16 | 20 | 18 | 9 |
| Right 3 | 1 | 24 | 23 | 23.5 | 36 | 37 | 36.5 | 13 |
| | 2 | 26 | 23 | 24.5 | 35 | 37 | 36 | 11.5 |
| Right 2 | 1 | 27 | 32 | 29.5 | 39 | 48 | 43.5 | 14 |
| | 2 | 20 | 23 | 21.5 | 35 | 42 | 38.5 | 17 |

| | | |
|---|---|---|
| Name | 13 | F |
| Age | 44 | y |
| Height | 65 | in |
| Weight | 168 | lb |

Values are in (mm)

| Detector | Scan | Fat 1 | Fat 2 | FatAvg | Tot 1 | Tot 2 | TotAvg | MuscAvg |
|---|---|---|---|---|---|---|---|---|
| Left 1 | 1 | 7 | 9 | 8 | 21 | 22 | 21.5 | 13.5 |
| | 2 | 7 | 7 | 7 | 17 | 18 | 17.5 | 10.5 |
| Left 3 | 1 | 14 | 11 | 12.5 | 37 | 51 | 44 | 31.5 |
| | 2 | 31 | 42 | 36.5 | 51 | 59 | 55 | 18.5 |
| Left 2 | 1 | 12 | 17 | 14.5 | 31 | 41 | 36 | 21.5 |
| | 2 | 16 | 20 | 18 | 35 | 40 | 37.5 | 19.5 |
| Right 1 | 1 | 8 | 11 | 9.5 | 16 | 19 | 17.5 | 8 |
| | 2 | 8 | 12 | 10 | 24 | 31 | 27.5 | 17.5 |
| Right 3 | 1 | 27 | 27 | 27 | 38 | 47 | 42.5 | 15.5 |
| | 2 | 32 | 32 | 32 | 51 | 47 | 49 | 17 |
| Right 2 | 1 | 16 | 25 | 20.5 | 30 | 42 | 36 | 15.5 |
| | 2 | 34 | 39 | 36.5 | 47 | 51 | 49 | 12.5 |

| | | |
|---|---|---|
| Name | 14 | F |
| Age | 40 | y |
| Height | 63.5 | in |
| Weight | 125 | lb |

| Detector | Scan | Fat 1 | Fat 2 | FatAvg | Tot 1 | Tot 2 | TotAvg | MuscAvg |
|---|---|---|---|---|---|---|---|---|
| Left 1 | 1 | 5 | 7 | 6 | 15 | 17 | 16 | 10 |
| | 2 | 5 | 7 | 6 | 13 | 15 | 14 | 8 |
| Left 3 | 1 | 13 | 22 | 17.5 | 32 | 37 | 34.5 | 17 |
| | 2 | 13 | 22 | 17.5 | 35 | 41 | 38 | 20.5 |
| Left 2 | 1 | 8 | 13 | 10.5 | 17 | 27 | 22 | 11.5 |
| | 2 | 13 | 22 | 17.5 | 27 | 35 | 31 | 13.5 |
| Right 1 | 1 | 6 | 8 | 7 | 15 | 19 | 17 | 10 |
| | 2 | 3 | 10 | 6.5 | 15 | 21 | 18 | 11.5 |
| Right 3 | 1 | 9 | 13 | 11 | 28 | 27 | 27.5 | 16.5 |
| | 2 | 8 | 9 | 8.5 | 32 | 30 | 31 | 22.5 |
| Right 2 | 1 | 11 | 19 | 15 | 26 | 37 | 31.5 | 16.5 |
| | 2 | 11 | 20 | 15.5 | 32 | 41 | 36.5 | 21 |

| | | |
|---|---|---|
| Name | 15 | F |
| Age | 28 | y |
| Height | 68.75 | in |
| Weight | 155.8 | lb |

| Detector | Scan | Fat 1 | Fat 2 | FatAvg | Tot 1 | Tot 2 | TotAvg | MuscAvg |
|---|---|---|---|---|---|---|---|---|
| Left 1 | 1 | 6 | 6 | 6 | 15 | 20 | 17.5 | 11.5 |
| | 2 | 7 | 12 | 9.5 | 22 | 23 | 22.5 | 13 |
| Left 3 | 1 | 23 | 32 | 27.5 | 39 | 51 | 45 | 17.5 |
| | 2 | 27 | 40 | 33.5 | 48 | 59 | 53.5 | 20 |
| Left 2 | 1 | 12 | 22 | 17 | 25 | 32 | 28.5 | 11.5 |
| | 2 | 17 | 26 | 21.5 | 31 | 39 | 35 | 13.5 |
| Right 1 | 1 | 7 | 7 | 7 | 17 | 19 | 18 | 11 |
| | 2 | 5 | 7 | 6 | 17 | 22 | 19.5 | 13.5 |
| Right 3 | 1 | 18 | 25 | 21.5 | 44 | 46 | 45 | 23.5 |
| | 2 | 28 | 40 | 34 | 45 | 56 | 50.5 | 16.5 |
| Right 2 | 1 | 20 | 23 | 21.5 | 37 | 42 | 39.5 | 18 |
| | 2 | 25 | 30 | 27.5 | 39 | 43 | 41 | 13.5 |

| | | |
|---|---|---|
| Name | 16 | F |
| Age | 34 | y |
| Height | 62 | in |
| Weight | 136.2 | lb |

Values are in (mm)

| Detector | Scan | Fat 1 | Fat 2 | FatAvg | Tot 1 | Tot 2 | TotAvg | MuscAvg |
|---|---|---|---|---|---|---|---|---|
| Left 1 | 1 | 8 | 8 | 8 | 17 | 21 | 19 | 11 |
| | 2 | 9 | 9 | 9 | 20 | 23 | 21.5 | 12.5 |
| Left 3 | 1 | 22 | 20 | 21 | 47 | 42 | 44.5 | 23.5 |
| | 2 | 32 | 42 | 37 | 51 | 58 | 54.5 | 17.5 |
| Left 2 | 1 | 17 | 28 | 22.5 | 32 | 40 | 36 | 13.5 |
| | 2 | 28 | 36 | 32 | 43 | 55 | 49 | 17 |
| Right 1 | 1 | 8 | 10 | 9 | 18 | 23 | 20.5 | 11.5 |
| | 2 | 7 | 11 | 9 | 20 | 27 | 23.5 | 14.5 |
| Right 3 | 1 | 17 | 27 | 22 | 33 | 45 | 39 | 17 |
| | 2 | 14 | 27 | 20.5 | 37 | 44 | 40.5 | 20 |
| Right 2 | 1 | 22 | 18 | 20 | 38 | 34 | 36 | 16 |
| | 2 | 24 | 22 | 23 | 37 | 38 | 37.5 | 14.5 |

| | | |
|---|---|---|
| Name | 17 | F |
| Age | 39 | y |
| Height | 68.25 | in |
| Weight | 176 | lb |

| Detector | Scan | Fat 1 | Fat 2 | FatAvg | Tot 1 | Tot 2 | TotAvg | MuscAvg |
|---|---|---|---|---|---|---|---|---|
| Left 1 | 1 | 11 | 12 | 11.5 | 25 | 27 | 26 | 14.5 |
| | 2 | 13 | 17 | 15 | 28 | 32 | 30 | 15 |
| Left 3 | 1 | 52 | 60 | 56 | 68 | 81 | 74.5 | 18.5 |
| | 2 | 49 | 57 | 53 | 67 | 74 | 70.5 | 17.5 |
| Left 2 | 1 | 15 | 27 | 21 | 41 | 43 | 42 | 21 |
| | 2 | 37 | 39 | 38 | 49 | 52 | 50.5 | 12.5 |
| Right 1 | 1 | 10 | 8 | 9 | 22 | 31 | 26.5 | 17.5 |
| | 2 | 10 | 11 | 10.5 | 30 | 34 | 32 | 21.5 |
| Right 3 | 1 | 27 | 41 | 34 | 57 | 70 | 63.5 | 29.5 |
| | 2 | 36 | 47 | 41.5 | 57 | 64 | 60.5 | 19 |
| Right 2 | 1 | 28 | 30 | 29 | 57 | 67 | 62 | 33 |
| | 2 | 42 | 48 | 45 | 68 | 71 | 69.5 | 24.5 |

| | | |
|---|---|---|
| Name | 18 | F |
| Age | 27 | y |
| Height | 62 | in |
| Weight | 122.6 | lb |

| Detector | Scan | Fat 1 | Fat 2 | FatAvg | Tot 1 | Tot 2 | TotAvg | MuscAvg |
|---|---|---|---|---|---|---|---|---|
| Left 1 | 1 | 7 | 9 | 8 | 18 | 21 | 19.5 | 11.5 |
| | 2 | 8 | 12 | 10 | 17 | 22 | 19.5 | 9.5 |
| Left 3 | 1 | 23 | 27 | 25 | 35 | 39 | 37 | 12 |
| | 2 | 28 | 32 | 30 | 36 | 44 | 40 | 10 |
| Left 2 | 1 | 12 | 19 | 15.5 | 25 | 31 | 28 | 12.5 |
| | 2 | 11 | 15 | 13 | 27 | 31 | 29 | 16 |
| Right 1 | 1 | 8 | 13 | 10.5 | 18 | 23 | 20.5 | 10 |
| | 2 | 14 | 20 | 17 | 27 | 35 | 31 | 14 |
| Right 3 | 1 | 21 | 22 | 21.5 | 37 | 34 | 35.5 | 14 |
| | 2 | 28 | 25 | 26.5 | 43 | 37 | 40 | 13.5 |
| Right 2 | 1 | 27 | 32 | 29.5 | 35 | 43 | 39 | 9.5 |
| | 2 | 19 | 24 | 21.5 | 34 | 38 | 36 | 14.5 |

| | | |
|---|---|---|
| Name | 19 | F |
| Age | 42 | y |
| Height | 68.25 | in |
| Weight | 147.6 | lb |

Values are in (mm)

| Detector | Scan | Fat 1 | Fat 2 | FatAvg | Tot 1 | Tot 2 | TotAvg | MuscAvg |
|---|---|---|---|---|---|---|---|---|
| Left 1 | 1 | 10 | 13 | 11.5 | 18 | 26 | 22 | 10.5 |
| | 2 | 11 | 13 | 12 | 21 | 25 | 23 | 11 |
| Left 3 | 1 | 36 | 43 | 39.5 | 48 | 61 | 54.5 | 15 |
| | 2 | 43 | 52 | 47.5 | 52 | 59 | 55.5 | 8 |
| Left 2 | 1 | 30 | 39 | 34.5 | 39 | 47 | 43 | 8.5 |
| | 2 | 36 | 42 | 39 | 42 | 47 | 44.5 | 5.5 |
| Right 1 | 1 | 11 | 11 | 11 | 21 | 26 | 23.5 | 12.5 |
| | 2 | 11 | 12 | 11.5 | 19 | 26 | 22.5 | 11 |
| Right 3 | 1 | 32 | 41 | 36.5 | 37 | 48 | 42.5 | 6 |
| | 2 | 42 | 50 | 46 | 51 | 60 | 55.5 | 9.5 |
| Right 2 | 1 | 31 | 35 | 33 | 40 | 43 | 41.5 | 8.5 |
| | 2 | 39 | 40 | 39.5 | 44 | 51 | 47.5 | 8 |

| | | |
|---|---|---|
| Name | 20 | F |
| Age | 56 | y |
| Height | 62.75 | in |
| Weight | 123.2 | lb |

| Detector | Scan | Fat 1 | Fat 2 | FatAvg | Tot 1 | Tot 2 | TotAvg | MuscAvg |
|---|---|---|---|---|---|---|---|---|
| Left 1 | 1 | 7 | 10 | 8.5 | 18 | 23 | 20.5 | 12 |
| | 2 | 7 | 12 | 9.5 | 19 | 25 | 22 | 12.5 |
| Left 3 | 1 | 20 | 29 | 24.5 | 40 | 48 | 44 | 19.5 |
| | 2 | 27 | 31 | 29 | 39 | 46 | 42.5 | 13.5 |
| Left 2 | 1 | 20 | 29 | 24.5 | 33 | 44 | 38.5 | 14 |
| | 2 | 25 | 42 | 33.5 | 38 | 57 | 47.5 | 14 |
| Right 1 | 1 | 8 | 12 | 10 | 17 | 26 | 21.5 | 11.5 |
| | 2 | 10 | 16 | 13 | 22 | 31 | 26.5 | 13.5 |
| Right 3 | 1 | 30 | 37 | 33.5 | 43 | 48 | 45.5 | 12 |
| | 2 | 29 | 32 | 30.5 | 43 | 42 | 42.5 | 12 |
| Right 2 | 1 | 27 | 31 | 29 | 42 | 52 | 47 | 18 |
| | 2 | 34 | 42 | 38 | 48 | 62 | 55 | 17 |

| | | |
|---|---|---|
| Name | 21 | F |
| Age | 44 | y |
| Height | 66.5 | in |
| Weight | 185.6 | lb |

| Detector | Scan | Fat 1 | Fat 2 | FatAvg | Tot 1 | Tot 2 | TotAvg | MuscAvg |
|---|---|---|---|---|---|---|---|---|
| Left 1 | 1 | 9 | 9 | 9 | 22 | 23 | 22.5 | 13.5 |
| | 2 | 13 | 14 | 13.5 | 24 | 29 | 26.5 | 13 |
| Left 3 | 1 | 42 | 59 | 50.5 | 60 | 76 | 68 | 17.5 |
| | 2 | 50 | 55 | 52.5 | 62 | 77 | 69.5 | 17 |
| Left 2 | 1 | 54 | 57 | 55.5 | 71 | 69 | 70 | 14.5 |
| | 2 | 53 | 62 | 57.5 | 69 | 72 | 70.5 | 13 |
| Right 1 | 1 | 10 | 13 | 11.5 | 24 | 30 | 27 | 15.5 |
| | 2 | 12 | 13 | 12.5 | 34 | 48 | 41 | 28.5 |
| Right 3 | 1 | 49 | 52 | 50.5 | 58 | 65 | 61.5 | 11 |
| | 2 | 44 | 51 | 47.5 | 57 | 64 | 60.5 | 13 |
| Right 2 | 1 | 51 | 52 | 51.5 | 61 | 65 | 63 | 11.5 |
| | 2 | 53 | 63 | 58 | 64 | 77 | 70.5 | 12.5 |

| | | |
|---|---|---|
| Name | 22 | F |
| Age | 50 | y |
| Height | 66.75 | in |
| Weight | 136.2 | lb |

Values are in (mm)

| Detector | Scan | Fat 1 | Fat 2 | FatAvg | Tot 1 | Tot 2 | TotAvg | MuscAvg |
|---|---|---|---|---|---|---|---|---|
| Left 1 | 1 | 7 | 7 | 7 | 17 | 19 | 18 | 11 |
| | 2 | 10 | 11 | 10.5 | 17 | 19 | 18 | 7.5 |
| Left 3 | 1 | 17 | 26 | 21.5 | 28 | 34 | 31 | 9.5 |
| | 2 | 29 | 32 | 30.5 | 38 | 45 | 41.5 | 11 |
| Left 2 | 1 | 8 | 7 | 7.5 | 25 | 31 | 28 | 20.5 |
| | 2 | 32 | 39 | 35.5 | 42 | 52 | 47 | 11.5 |
| Right 1 | 1 | 7 | 9 | 8 | 20 | 22 | 21 | 13 |
| | 2 | 9 | 12 | 10.5 | 18 | 23 | 20.5 | 10 |
| Right 3 | 1 | 26 | 34 | 30 | 37 | 43 | 40 | 10 |
| | 2 | 31 | 35 | 33 | 41 | 42 | 41.5 | 8.5 |
| Right 2 | 1 | 27 | 29 | 28 | 36 | 39 | 37.5 | 9.5 |
| | 2 | 34 | 40 | 37 | 42 | 48 | 45 | 8 |

| | | |
|---|---|---|
| Name | 23 | F |
| Age | 49 | y |
| Height | 63 | in |
| Weight | 134 | lb |

| Detector | Scan | Fat 1 | Fat 2 | FatAvg | Tot 1 | Tot 2 | TotAvg | MuscAvg |
|---|---|---|---|---|---|---|---|---|
| Left 1 | 1 | 8 | 7 | 7.5 | 18 | 22 | 20 | 12.5 |
| | 2 | 11 | 10 | 10.5 | 21 | 22 | 21.5 | 11 |
| Left 3 | 1 | 32 | 39 | 35.5 | 47 | 52 | 49.5 | 14 |
| | 2 | 38 | 38 | 38 | 53 | 54 | 53.5 | 15.5 |
| Left 2 | 1 | 32 | 37 | 34.5 | 47 | 56 | 51.5 | 17 |
| | 2 | 43 | 50 | 46.5 | 64 | 65 | 64.5 | 18 |
| Right 1 | 1 | 10 | 21 | 15.5 | 21 | 30 | 25.5 | 10 |
| | 2 | 14 | 22 | 18 | 22 | 34 | 28 | 10 |
| Right 3 | 1 | 38 | 44 | 41 | 48 | 56 | 52 | 11 |
| | 2 | 32 | 35 | 33.5 | 44 | 48 | 46 | 12.5 |
| Right 2 | 1 | 28 | 35 | 31.5 | 52 | 60 | 56 | 24.5 |
| | 2 | 38 | 47 | 42.5 | 54 | 63 | 58.5 | 16 |

| | | |
|---|---|---|
| Name | 24 | F |
| Age | 39 | y |
| Height | 66.5 | in |
| Weight | 186.4 | lb |

| Detector | Scan | Fat 1 | Fat 2 | FatAvg | Tot 1 | Tot 2 | TotAvg | MuscAvg |
|---|---|---|---|---|---|---|---|---|
| Left 1 | 1 | 11 | 13 | 12 | 24 | 30 | 27 | 15 |
| | 2 | 11 | 17 | 14 | 31 | 44 | 37.5 | 23.5 |
| Left 3 | 1 | 21 | 21 | 21 | 55 | 57 | 56 | 35 |
| | 2 | 34 | 37 | 35.5 | 59 | 59 | 59 | 23.5 |
| Left 2 | 1 | 42 | 46 | 44 | 56 | 59 | 57.5 | 13.5 |
| | 2 | 50 | 56 | 53 | 62 | 68 | 65 | 12 |
| Right 1 | 1 | 9 | 12 | 10.5 | 27 | 32 | 29.5 | 19 |
| | 2 | 12 | 9 | 10.5 | 30 | 40 | 35 | 24.5 |
| Right 3 | 1 | 40 | 44 | 42 | 55 | 55 | 55 | 13 |
| | 2 | 43 | 48 | 45.5 | 60 | 60 | 60 | 14.5 |
| Right 2 | 1 | 40 | 44 | 42 | 52 | 61 | 56.5 | 14.5 |
| | 2 | 37 | 54 | 45.5 | 54 | 67 | 60.5 | 15 |

| | | |
|---|---|---|
| Name | 25 | F |
| Age | 30 | y |
| Height | 62 | in |
| Weight | 185.6 | lb |

Values are in (mm)

| Detector | Scan | Fat 1 | Fat 2 | FatAvg | Tot 1 | Tot 2 | TotAvg | MuscAvg |
|---|---|---|---|---|---|---|---|---|
| Left 1 | 1 | 10 | 11 | 10.5 | 26 | 27 | 26.5 | 16 |
| | 2 | 12 | 14 | 13 | 33 | 36 | 34.5 | 21.5 |
| Left 3 | 1 | 27 | 42 | 34.5 | 52 | 56 | 54 | 19.5 |
| | 2 | 44 | 44 | 44 | 59 | 60 | 59.5 | 15.5 |
| Left 2 | 1 | 24 | 29 | 26.5 | 40 | 47 | 43.5 | 17 |
| | 2 | 42 | 46 | 44 | 59 | 56 | 57.5 | 13.5 |
| Right 1 | 1 | 14 | 12 | 13 | 29 | 32 | 30.5 | 17.5 |
| | 2 | 14 | 13 | 13.5 | 30 | 32 | 31 | 17.5 |
| Right 3 | 1 | 32 | 40 | 36 | 47 | 51 | 49 | 13 |
| | 2 | 34 | 41 | 37.5 | 49 | 51 | 50 | 12.5 |
| Right 2 | 1 | 30 | 26 | 28 | 43 | 42 | 42.5 | 14.5 |
| | 2 | 27 | 32 | 29.5 | 46 | 54 | 50 | 20.5 |

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| | | |
|---|---|---|
| Name | 26 | F |
| Age | 41 | y |
| Height | 65.25 | in |
| Weight | 173.2 | lb |

| Detector | Scan | Fat 1 | Fat 2 | FatAvg | Tot 1 | Tot 2 | TotAvg | MuscAvg |
|---|---|---|---|---|---|---|---|---|
| Left 1 | 1 | 13 | 17 | 15 | 22 | 26 | 24 | 9 |
| | 2 | 12 | 11 | 11.5 | 26 | 29 | 27.5 | 16 |
| Left 3 | 1 | 32 | 38 | 35 | 46 | 59 | 52.5 | 17.5 |
| | 2 | 37 | 40 | 38.5 | 49 | 56 | 52.5 | 14 |
| Left 2 | 1 | 22 | 27 | 24.5 | 37 | 40 | 38.5 | 14 |
| | 2 | 33 | 46 | 39.5 | 43 | 52 | 47.5 | 8 |
| Right 1 | 1 | 11 | 13 | 12 | 22 | 28 | 25 | 13 |
| | 2 | 11 | 11 | 11 | 23 | 21 | 22 | 11 |
| Right 3 | 1 | 21 | 27 | 24 | 37 | 43 | 40 | 16 |
| | 2 | 32 | 30 | 31 | 42 | 44 | 43 | 12 |
| Right 2 | 1 | 33 | 34 | 33.5 | 47 | 52 | 49.5 | 16 |
| | 2 | 32 | 34 | 33 | 49 | 69 | 59 | 26 |

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| | | |
|---|---|---|
| Name | 27 | F |
| Age | 37 | y |
| Height | 64.5 | in |
| Weight | 160.6 | lb |

| Detector | Scan | Fat 1 | Fat 2 | FatAvg | Tot 1 | Tot 2 | TotAvg | MuscAvg |
|---|---|---|---|---|---|---|---|---|
| Left 1 | 1 | 7 | 9 | 8 | 17 | 22 | 19.5 | 11.5 |
| | 2 | 8 | 12 | 10 | 17 | 22 | 19.5 | 9.5 |
| Left 3 | 1 | 34 | 42 | 38 | 46 | 54 | 50 | 12 |
| | 2 | 37 | 40 | 38.5 | 47 | 50 | 48.5 | 10 |
| Left 2 | 1 | 27 | 31 | 29 | 37 | 41 | 39 | 10 |
| | 2 | 23 | 42 | 32.5 | 42 | 54 | 48 | 15.5 |
| Right 1 | 1 | 7 | 12 | 9.5 | 17 | 27 | 22 | 12.5 |
| | 2 | 9 | 14 | 11.5 | 23 | 29 | 26 | 14.5 |
| Right 3 | 1 | 32 | 42 | 37 | 51 | 58 | 54.5 | 17.5 |
| | 2 | 42 | 42 | 42 | 52 | 52 | 52 | 10 |
| Right 2 | 1 | 40 | 47 | 43.5 | 47 | 57 | 52 | 8.5 |
| | 2 | 53 | 62 | 57.5 | 62 | 75 | 68.5 | 11 |

| | | |
|---|---|---|
| Name | 28 | F |
| Age | 61 | y |
| Height | 64.25 | in |
| Weight | 115.4 | lb |

Values are in (mm)

| Detector | Scan | Fat 1 | Fat 2 | FatAvg | Tot 1 | Tot 2 | TotAvg | MuscAvg |
|---|---|---|---|---|---|---|---|---|
| Left 1 | 1 | 7 | 10 | 8.5 | 17 | 21 | 19 | 10.5 |
| | 2 | 8 | 10 | 9 | 17 | 17 | 17 | 8 |
| Left 3 | 1 | 18 | 24 | 21 | 27 | 36 | 31.5 | 10.5 |
| | 2 | 25 | 31 | 28 | 34 | 36 | 35 | 7 |
| Left 2 | 1 | 21 | 27 | 24 | 30 | 39 | 34.5 | 10.5 |
| | 2 | 23 | 30 | 26.5 | 32 | 42 | 37 | 10.5 |
| Right 1 | 1 | 8 | 11 | 9.5 | 17 | 27 | 22 | 12.5 |
| | 2 | 8 | 10 | 9 | 16 | 21 | 18.5 | 9.5 |
| Right 3 | 1 | 25 | 26 | 25.5 | 32 | 36 | 34 | 8.5 |
| | 2 | 27 | 32 | 29.5 | 33 | 39 | 36 | 6.5 |
| Right 2 | 1 | 22 | 26 | 24 | 31 | 35 | 33 | 9 |
| | 2 | 24 | 23 | 23.5 | 34 | 39 | 36.5 | 13 |

| | | |
|---|---|---|
| Name | 29 | F |
| Age | 29 | y |
| Height | 68 | in |
| Weight | 126.2 | lb |

| Detector | Scan | Fat 1 | Fat 2 | FatAvg | Tot 1 | Tot 2 | TotAvg | MuscAvg |
|---|---|---|---|---|---|---|---|---|
| Left 1 | 1 | 8 | 9 | 8.5 | 16 | 18 | 17 | 8.5 |
| | 2 | 12 | 9 | 10.5 | 26 | 17 | 21.5 | 11 |
| Left 3 | 1 | 18 | 21 | 19.5 | 29 | 32 | 30.5 | 11 |
| | 2 | 20 | 19 | 19.5 | 28 | 33 | 30.5 | 11 |
| Left 2 | 1 | 21 | 26 | 23.5 | 37 | 41 | 39 | 15.5 |
| | 2 | 22 | 22 | 22 | 32 | 32 | 32 | 10 |
| Right 1 | 1 | 7 | 8 | 7.5 | 15 | 18 | 16.5 | 9 |
| | 2 | 6 | 10 | 8 | 15 | 19 | 17 | 9 |
| Right 3 | 1 | 17 | 19 | 18 | 25 | 32 | 28.5 | 10.5 |
| | 2 | 21 | 23 | 22 | 27 | 31 | 29 | 7 |
| Right 2 | 1 | 22 | 27 | 24.5 | 31 | 39 | 35 | 10.5 |
| | 2 | 20 | 27 | 23.5 | 30 | 37 | 33.5 | 10 |

| | | |
|---|---|---|
| Name | 30 | F |
| Age | 37 | y |
| Height | 64 | in |
| Weight | 146.6 | lb |

| Detector | Scan | Fat 1 | Fat 2 | FatAvg | Tot 1 | Tot 2 | TotAvg | MuscAvg |
|---|---|---|---|---|---|---|---|---|
| Left 1 | 1 | 6 | 7 | 6.5 | 18 | 18 | 18 | 11.5 |
| | 2 | 7 | 8 | 7.5 | 19 | 23 | 21 | 13.5 |
| Left 3 | 1 | 31 | 34 | 32.5 | 40 | 46 | 43 | 10.5 |
| | 2 | 37 | 39 | 38 | 47 | 52 | 49.5 | 11.5 |
| Left 2 | 1 | 15 | 18 | 16.5 | 27 | 31 | 29 | 12.5 |
| | 2 | 19 | 30 | 24.5 | 35 | 39 | 37 | 12.5 |
| Right 1 | 1 | 6 | 7 | 6.5 | 17 | 17 | 17 | 10.5 |
| | 2 | 7 | 9 | 8 | 17 | 18 | 17.5 | 9.5 |
| Right 3 | 1 | 27 | 32 | 29.5 | 37 | 45 | 41 | 11.5 |
| | 2 | 30 | 32 | 31 | 42 | 43 | 42.5 | 11.5 |
| Right 2 | 1 | 14 | 20 | 17 | 27 | 34 | 30.5 | 13.5 |
| | 2 | 21 | 27 | 24 | 30 | 36 | 33 | 9 |

| | | |
|---|---|---|
| Name | 31 | F |
| Age | 41 | y |
| Height | 64 | in |
| Weight | 160.6 | lb |

Values are in (mm)

| Detector | Scan | Fat 1 | Fat 2 | FatAvg | Tot 1 | Tot 2 | TotAvg | MuscAvg |
|---|---|---|---|---|---|---|---|---|
| Left 1 | 1 | 8 | 11 | 9.5 | 25 | 27 | 26 | 16.5 |
| | 2 | 17 | 23 | 20 | 27 | 32 | 29.5 | 9.5 |
| Left 3 | 1 | 29 | 36 | 32.5 | 44 | 57 | 50.5 | 18 |
| | 2 | 40 | 46 | 43 | 50 | 58 | 54 | 11 |
| Left 2 | 1 | 25 | 33 | 29 | 36 | 40 | 38 | 9 |
| | 2 | 29 | 34 | 31.5 | 37 | 46 | 41.5 | 10 |
| Right 1 | 1 | 14 | 15 | 14.5 | 25 | 27 | 26 | 11.5 |
| | 2 | 12 | 21 | 16.5 | 25 | 30 | 27.5 | 11 |
| Right 3 | 1 | 32 | 39 | 35.5 | 42 | 54 | 48 | 12.5 |
| | 2 | 43 | 45 | 44 | 52 | 54 | 53 | 9 |
| Right 2 | 1 | 25 | 32 | 28.5 | 35 | 44 | 39.5 | 11 |
| | 2 | 27 | 33 | 30 | 37 | 50 | 43.5 | 13.5 |

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| | | |
|---|---|---|
| Name | 32 | F |
| Age | 44 | y |
| Height | 66.5 | in |
| Weight | 113.8 | lb |

| Detector | Scan | Fat 1 | Fat 2 | FatAvg | Tot 1 | Tot 2 | TotAvg | MuscAvg |
|---|---|---|---|---|---|---|---|---|
| Left 1 | 1 | 6 | 7 | 6.5 | 17 | 18 | 17.5 | 11 |
| | 2 | 6 | 12 | 9 | 14 | 22 | 18 | 9 |
| Left 3 | 1 | 28 | 32 | 30 | 40 | 42 | 41 | 11 |
| | 2 | 15 | 17 | 16 | 26 | 29 | 27.5 | 11.5 |
| Left 2 | 1 | 22 | 22 | 22 | 32 | 33 | 32.5 | 10.5 |
| | 2 | 22 | 26 | 24 | 31 | 37 | 34 | 10 |
| Right 1 | 1 | 9 | 8 | 8.5 | 22 | 27 | 24.5 | 16 |
| | 2 | 12 | 10 | 11 | 24 | 28 | 26 | 15 |
| Right 3 | 1 | 22 | 27 | 24.5 | 37 | 42 | 39.5 | 15 |
| | 2 | 24 | 29 | 26.5 | 34 | 40 | 37 | 10.5 |
| Right 2 | 1 | 22 | 24 | 23 | 32 | 33 | 32.5 | 9.5 |
| | 2 | 22 | 27 | 24.5 | 34 | 37 | 35.5 | 11 |

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| | | |
|---|---|---|
| Name | 33 | F |
| Age | 38 | y |
| Height | 65.25 | in |
| Weight | 121.8 | lb |

| Detector | Scan | Fat 1 | Fat 2 | FatAvg | Tot 1 | Tot 2 | TotAvg | MuscAvg |
|---|---|---|---|---|---|---|---|---|
| Left 1 | 1 | 7 | 15 | 11 | 18 | 24 | 21 | 10 |
| | 2 | 7 | 12 | 9.5 | 17 | 21 | 19 | 9.5 |
| Left 3 | 1 | 24 | 31 | 27.5 | 32 | 43 | 37.5 | 10 |
| | 2 | 24 | 28 | 26 | 31 | 42 | 36.5 | 10.5 |
| Left 2 | 1 | 16 | 22 | 19 | 28 | 32 | 30 | 11 |
| | 2 | 23 | 25 | 24 | 32 | 34 | 33 | 9 |
| Right 1 | 1 | 6 | 8 | 7 | 17 | 20 | 18.5 | 11.5 |
| | 2 | 12 | 20 | 16 | 19 | 27 | 23 | 7 |
| Right 3 | 1 | 22 | 32 | 27 | 33 | 40 | 36.5 | 9.5 |
| | 2 | 22 | 30 | 26 | 32 | 39 | 35.5 | 9.5 |
| Right 2 | 1 | 19 | 23 | 21 | 29 | 32 | 30.5 | 9.5 |
| | 2 | 27 | 34 | 30.5 | 39 | 43 | 41 | 10.5 |

| | | |
|---|---|---|
| Name | 34 | F |
| Age | 43 | y |
| Height | 69.25 | in |
| Weight | 154.2 | lb |

Values are in (mm)

| Detector | Scan | Fat 1 | Fat 2 | FatAvg | Tot 1 | Tot 2 | TotAvg | MuscAvg |
|---|---|---|---|---|---|---|---|---|
| Left 1 | 1 | 10 | 15 | 12.5 | 22 | 27 | 24.5 | 12 |
| | 2 | 12 | 17 | 14.5 | 22 | 28 | 25 | 10.5 |
| Left 3 | 1 | 29 | 34 | 31.5 | 37 | 47 | 42 | 10.5 |
| | 2 | 33 | 32 | 32.5 | 44 | 43 | 43.5 | 11 |
| Left 2 | 1 | 27 | 27 | 27 | 36 | 35 | 35.5 | 8.5 |
| | 2 | 27 | 30 | 28.5 | 37 | 38 | 37.5 | 9 |
| Right 1 | 1 | 7 | 12 | 9.5 | 17 | 25 | 21 | 11.5 |
| | 2 | 9 | 17 | 13 | 20 | 26 | 23 | 10 |
| Right 3 | 1 | 26 | 31 | 28.5 | 35 | 39 | 37 | 8.5 |
| | 2 | 32 | 37 | 34.5 | 41 | 46 | 43.5 | 9 |
| Right 2 | 1 | 27 | 28 | 27.5 | 35 | 37 | 36 | 8.5 |
| | 2 | 30 | 38 | 34 | 41 | 48 | 44.5 | 10.5 |

| | | |
|---|---|---|
| Name | 35 | F |
| Age | 28 | y |
| Height | 65.5 | in |
| Weight | 134.2 | lb |

| Detector | Scan | Fat 1 | Fat 2 | FatAvg | Tot 1 | Tot 2 | TotAvg | MuscAvg |
|---|---|---|---|---|---|---|---|---|
| Left 1 | 1 | 7 | 11 | 9 | 22 | 27 | 24.5 | 15.5 |
| | 2 | 6 | 10 | 8 | 18 | 20 | 19 | 11 |
| Left 3 | 1 | 17 | 25 | 21 | 37 | 41 | 39 | 18 |
| | 2 | 32 | 37 | 34.5 | 46 | 48 | 47 | 12.5 |
| Left 2 | 1 | 10 | 17 | 13.5 | 26 | 27 | 26.5 | 13 |
| | 2 | 22 | 30 | 26 | 32 | 40 | 36 | 10 |
| Right 1 | 1 | 10 | 17 | 13.5 | 23 | 33 | 28 | 14.5 |
| | 2 | 10 | 14 | 12 | 27 | 32 | 29.5 | 17.5 |
| Right 3 | 1 | 27 | 30 | 28.5 | 45 | 43 | 44 | 15.5 |
| | 2 | 31 | 31 | 31 | 48 | 40 | 44 | 13 |
| Right 2 | 1 | 36 | 46 | 41 | 46 | 60 | 53 | 12 |
| | 2 | 31 | 37 | 34 | 43 | 57 | 50 | 16 |

| | | |
|---|---|---|
| Name | 36 | F |
| Age | 29 | y |
| Height | 64.25 | in |
| Weight | 136.6 | lb |

| Detector | Scan | Fat 1 | Fat 2 | FatAvg | Tot 1 | Tot 2 | TotAvg | MuscAvg |
|---|---|---|---|---|---|---|---|---|
| Left 1 | 1 | 10 | 12 | 11 | 20 | 27 | 23.5 | 12.5 |
| | 2 | 13 | 20 | 16.5 | 24 | 30 | 27 | 10.5 |
| Left 3 | 1 | 38 | 44 | 41 | 52 | 61 | 56.5 | 15.5 |
| | 2 | 42 | 48 | 45 | 57 | 63 | 60 | 15 |
| Left 2 | 1 | 23 | 29 | 26 | 38 | 42 | 40 | 14 |
| | 2 | 31 | 35 | 33 | 38 | 48 | 43 | 10 |
| Right 1 | 1 | 8 | 10 | 9 | 19 | 25 | 22 | 13 |
| | 2 | 12 | 21 | 16.5 | 21 | 29 | 25 | 8.5 |
| Right 3 | 1 | 44 | 52 | 48 | 54 | 67 | 60.5 | 12.5 |
| | 2 | 40 | 50 | 45 | 52 | 66 | 59 | 14 |
| Right 2 | 1 | 33 | 36 | 34.5 | 45 | 51 | 48 | 13.5 |
| | 2 | 37 | 45 | 41 | 52 | 58 | 55 | 14 |

| | | |
|---|---|---|
| Name | 37 | F |
| Age | 34 | y |
| Height | 64 | in |
| Weight | 109.8 | lb |

Values are in (mm)

| Detector | Scan | Fat 1 | Fat 2 | FatAvg | Tot 1 | Tot 2 | TotAvg | MuscAvg |
|---|---|---|---|---|---|---|---|---|
| Left 1 | 1 | 6 | 8 | 7 | 13 | 17 | 15 | 8 |
| | 2 | 7 | 8 | 7.5 | 14 | 17 | 15.5 | 8 |
| Left 3 | 1 | 21 | 32 | 26.5 | 37 | 46 | 41.5 | 15 |
| | 2 | 27 | 31 | 29 | 39 | 45 | 42 | 13 |
| Left 2 | 1 | 14 | 19 | 16.5 | 25 | 29 | 27 | 10.5 |
| | 2 | 34 | 37 | 35.5 | 42 | 44 | 43 | 7.5 |
| Right 1 | 1 | 6 | 9 | 7.5 | 15 | 20 | 17.5 | 10 |
| | 2 | 10 | 16 | 13 | 19 | 27 | 23 | 10 |
| Right 3 | 1 | 27 | 32 | 29.5 | 41 | 54 | 47.5 | 18 |
| | 2 | 27 | 32 | 29.5 | 39 | 47 | 43 | 13.5 |
| Right 2 | 1 | 17 | 25 | 21 | 28 | 37 | 32.5 | 11.5 |
| | 2 | 17 | 27 | 22 | 27 | 38 | 32.5 | 10.5 |

## APPENDIX C

## SYSTEM SPECIFICATIONS

Operating system

Siemens Gammasonics, Inc.: Model 2300 PHO/SONIC* Series 2000, Linear Array Dynamic Imaging System, Serial Number:

Display

Standard NTSC television format (525 lines, 60 fields/second) or CCIR 625/50 (option) Display is rotated 90° clockwise from conventional television orientation. Display size: 16 cm diagonal. Available brightness: 40 foot-lamberts

DISPLAY FIELD SIZES:

2.5 MHz/3.5 MHz probes, 20 or 15 cm depth, 11.4 cm wide equivalent distances

5.0 MHz probe 15 cm depth, 8.4 cm wide

7.0 MHz probe 10 cm depth, 6 cm wide

DISPLAY MAGNIFICATION:

2X expansion provides selectable 10 cm depth segment for 2.5 or 3.5 MHz probes, 7.5 cm for 5 MHz and 5 cm for 7.0 MHz. Displayed region variable over full field depth

DISPLAY LINES:

Active display lines, (NTSC format)

230 on 20 cm and 10 cm field

298 on 15 cm field (2.5/3.5 MHz)

458 on 2X expand

DISPLAY INDICATIONS:

Standard

16 Step gray scale

Transducer orientation

1 cm equivalent distance marks. Accuracy ± 0.5 % at assumed acoustic velocity of 1540 m/s

DISPLAY LINEARITY AND STABILITY:

Better than ± 2 % of diagonal dimension after 1 hour warm up

DISPLAY VIDEO INVERSION:

Displays echo signals as white on black or vice versa. TV OUTPUT/INPUT rear panel connections provide or accept TV signal at 75 ohms impedance. Display may be used to show TV signal from external source. Normal output maintained on output connections.

PHOTOGRAPHIC EXPOSURE:

Separate contrast and brightness controls automatically selected during photographic sequence

<u>CONTROLS AND INDICATIONS</u>

FRONT PANEL CONTROLS:

3 knob receiver depth gain control (NEAR, SLOPE and FAR)

Transmit level control

Field size selection, 3 push buttons

2X expansion

Expanded field position

Display left/right orientation

Camera set up

ON/OFF power switch

FRONT PANEL INDICATIONS:

LED indicators show:

Camera set up status

Probe type (cophase or focus) and frequency

Display orientation

Frozen image

Field size and magnification selected

LEFT SIDE PANEL:

Display brightness

Display contrast

Display source

Display polarity

Photographic brightness

Photographic contrast

Photographic exposure 1, 2 or 4 TV frames

Photo polarity

RIGHT SIDE PANEL:

Focus or cophase probe selection

REAR PANEL:

Video input termination

FRAME FREEZE

Type:

Digital storage of echo data frame with readout in television format

Size:

128 X 256 storage cells

Gray scale: 4 bits/cell (16 levels)

TRANSDUCERS (STANDARD)

A. 2.5 MHz Cophase Probe, 256 acoustic elements connected as 128 electrically. Active scan length = 11.4 cm; Weight: 550 grams; Size: 210 mm long, 45 mm thick, 110 mm high (envelope dimension)

B. 3.5 MHz Cophase probe/384 acoustic elements connected as 128 electrically. Other specifications same as for 2.5 MHz Cophase

All transducer frequencies are nominal center frequencies, ± 10 %

ACOUSTIC SCAN RATE for all probes:

30 complete acoustic scans/second (NTSC TV)

25 complete acoustic scans/second (CCIR TV)

CAMERA

LENS:

75 mm f/5.6

SHUTTER:

Electronic control

BACK:

Polaroid pack

FILM:

Polaroid types: 084, 667 or 107-084

SHUTTER AND DISPLAY SEQUENCE:

Automatically executed on activation of camera mounted SHUTTER release, probe mounted

CAMERA control or footswitch

VIEWING:

Viewing window with polarized filters allows direct viewing of display when camera is in place

ELECTRONIC CALIPERS

TYPE:

Two cross hair marks superimposed on image. Mark are shadowed to maintain visibility over all display brightness levels

OPERATION:

Joystick moves mark. SET pushbutton fixes one end of measured distance

READOUT:

On main display screen in millimeters

PRECISION:

Calculation and readout to ± 1 mm assuming 1540 m/s acoustic velocity

KEYBOARD AND ANNOTATION

READOUT:

Three lines of displayed characters in 7 X 8 dot matrix. Each line 24 characters maximum. Moving cursor indicates position.

CHARACTER SET:

26 alphabetic A-Z, 10 numeric 0-9, space (SP), period (.), comma (,)

CONTROL:

Backspace (BS), Carriage return (CR), Line feed (LF), Rub out (RUB), Special function (*).

AUTOMATIC FUNCTIONS:

AUTO DATA R/O. Shows identification and date fields, photograph sequence number, transducer frequency, transmit level setting and focal length if focused probe is in use. Preformatted subject identification and date entry are provided in this mode. Caliper and keyboard options are contained in detachable module.

FOCUSED PROBES

A. 2.5 MHz Focused probe. Elements and scan length as 2.5 MHz Cophase probe WEIGHT: 550 grams; SIZE: same as Cophase probe; FOCAL LENGTH: 9 cm

B. 3.5 MHz Focused probe. Elements and scan length as 3.5 MHz Cophase

Weight and size same as item 2.5 MHz focused probe; FOCAL LENGTH: 9 cm

HIGH FREQUENCY PROBES

A. 5.0 MHz Cophase probe. 256 acoustic elements connected as 128 elements electrically

ACTIVE SCAN LENGTH: 8.4 cm; WEIGHT and SIZE to be provided

B. 7.0 MHz Cophase probe. 256 acoustic elements connected as 128 elements electrically

ACTIVE SCAN LENGTH: 6 cm; WEIGHT and SIZE to be provided

ACOUSTIC RESOLUTION

| Probe Type | (1) Axial Resolution mm | (2) FWHM Lateral Resolution mm | (3) Depth of Field** mm |
|---|---|---|---|
| 2.5 MHz Coph. | 1.2 | 7.0*** | NA |
| 3.5 MHz Coph. | 0.7 | 5.0*** | NA |
| 2.5 MHz Foc. | 1.0 | 3.5* | 95 |
| 3.5 MHz Foc. | 0.7 | 3.0* | 96 |
| 5.0 MHz Coph. | TBP | TBP | TBP |
| 7.0 MHz Coph. | TBP | TBP | TBP |

* at focal point
** range interval about measurement point of (2) for less than 6 dB sensitivity change
*** at 9 cm range
TBP = to be provided

## ACOUSTIC POWER

| PROBE TYPE | SPATIAL AVG/ TEMPORAL AVG $mW/cm^2$ | SPATIAL PEAK/ TEMPORAL PEAK $W/cm^2$ | TOTAL POWER (TEMPORAL AVG) mW |
|---|---|---|---|
| 2.5 MHz Coph. | 0.11 | 1.3 | 0.11 |
| 3.5 MHz Coph. | 0.08 | 1.2 | 0.07 |
| 2.5 MHz Foc. | 0.52 | 3.5 | 0.36 |
| 3.5 MHz Foc. | 0.28 | 2.5 | 0.23 |
| 5.0 MHz Coph. | TBP | TBP | TBP |
| 7.0 MHz Coph. | TBP | TBP | TBP |

## POWER REQUIREMENTS

POWER SUPPLY:

90-110, 105-129, 195-239, or 210-250 VAC, 50-60 Hz

POWER CONSUMPTION:

150 VA

LEAKAGE CURRENT:

LESS THAN 100 $\mu$A at 250 Volts AC input

## ENVIRONMENTAL LIMITS

TEMPERATURE:

0 to 40°C

HUMIDITY:

0 to 90 % non condensing

ALTITUDE:

3000 meters

PHYSICAL

WIDTH:

43.0 cm

HEIGHT:

28.0 cm

DEPTH:

46.0 cm (with keyboard caliper option 57.0 cm)

WEIGHT:

25 kg

# VITA

Lisa Rene Vickers was born in Ocala, Florida, along with her triplet sisters Laurie and Linda, on November 10, 1967. She attended elementary schools in Norman, OK, Gulf Port, MS, and Panama City, FL. She graduated from Rutherford Sr. High School, of Panama City, in June, 1985. The following August she entered Gulf Coast Community College, of Panama City, and in May, 1988, she received the degree of Associate of Arts in pre-engineering. She continued her studies the following August at The University of Florida, Gainesville in the Nuclear Engineering Sciences Department, major: health physics, and in August, 1991, she received the degree of Bachelor of Science in Nuclear Engineering Sciences.

She is presently employed as a health physicist by Martin Marietta Energy Systems, Inc., at the K-25 Site, which is operated for the U.S. Department of Energy in Oak Ridge, Tennessee.