Abdominal Subcutaneous Adipose Tissue (DAT and SAT)

Since Vague's early work (Vague 1956) literature has consistently shown that adipose tissue distribution can be a more reliable predictor of chronic diseases then BMI or %BF (Aronne 2002b). In particular, abdominal adipose tissue which can be divided into subcutaneous and visceral depots can be an accurate predictor of coronary disease (Ohlson 1985), and type 2 diabetes (Chan et al 1994, Despres et al. 2001). The subcutaneous adipose depots can be further divided into superficial and deep compartments (see Figure 1) which are separated by subcutaneous fascia. The rationale for this division initially came from animal studies which indicate that lipids are depleted and deposited at a faster rate into the deep layer of the subcutaneous tissue then the superficial layer. This suggests that the superficial layer acts as a thermal insulation or storage layer whereas the deep layer functions as a metabolically active tissue (Carey 1997). These animal studies were confirmed by Monzon et al (2002) who reported that lipolytic activity was higher in adipocytes isolated from DAT compared with adipoctyes isolated from SAT. Kelly and colleagues (2000) report that DAT, but NOT SAT is strongly related to insulin resistance in a cohort of lean and obese men and women.

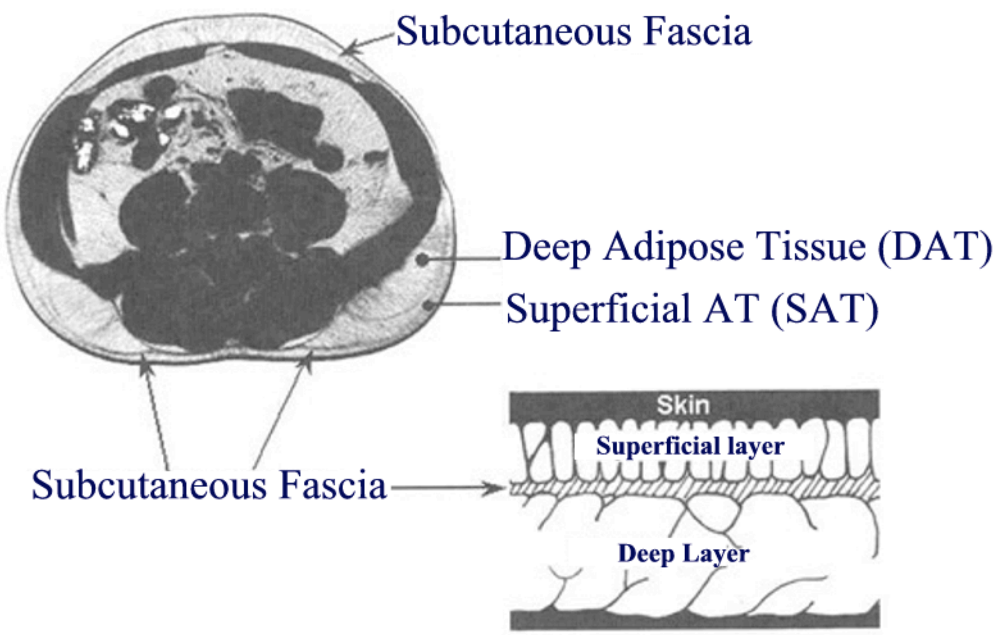

Figure 1 A CT image of the abdominal area of a male showing the key types of adipose tissue and how subcutaneous fascia separates the adipose tissue.

X-ray computed tomography (CT) and magnetic resonance imaging (MRI) are now considered the gold standard for measuring superficial, deep, and visceral adipose tissue thickness and volume. Figure 1 shows an example of a CT image of the abdomen. The light (adipose) and dark (muscle, bone, and organs) are clearly identifiable. Analysis of a series of CT images taken along the human body can provide very accurate measurements of body composition. Unfortunately, the high cost and radiation dose associated with CT makes this technique impractical for routine or regular body composition measurements. Although MRI imaging is safe it still remains a costly procedure and unlikely to become a routine screening tool for body composition. Another radiographic technique that is being used for body composition is dual energy x-ray absorption (DEXA). DEXA produces a two-dimensional image of the body which can be analyzed to calculate muscle, bone and adipose tissue weight and volume with accuracies approaching CT and MRI imaging. DEXA however, can not directly identify SAT and DAT.

Ultrasound technology has been evaluated in the past (Black 1988, Ribeiro-Filho 2003, Saito 2003) and offers an attractive alternative to X-ray and MRI techniques. Ultrasound imaging is now routinely used in a variety of clinical settings, including obstetrics and gynecology, cardiology, urology and cancer detection. The BodyMetrix system offers the ability to accurately measure %BF by making multiple site measurements of fat thickness. More importantly the BodyMetrix Ultrasound System can be used in scan mode to identify the SAT and DAT layers. Figure 2 belows shows an example of a cross-sectional scan taken from approximately 1 inch (~2.5 cm) to the right of the belly button to within approximately 3 inches (~ 8 cm) of the hip bone. The scan clearly shows the SAT layer, the subcutaneous fascia and the DAT. It's interesting to note that the SAT appears to have very little structure as indicated by the comparatively low ultrasound signal (dark). By contrast the DAT layer shows significant structure as indicated by the higher degree of ultrasound signal within the fat layer. This is most likely connective tissue, or arteries/capillaries within the fat layer. Figures 3 & 4 show other waist scans that illustrate how the BodyMetrix can be used to clearly visualize DAT and SAT layers in diverse populations.

Waist Scan of 50 Year Old Male

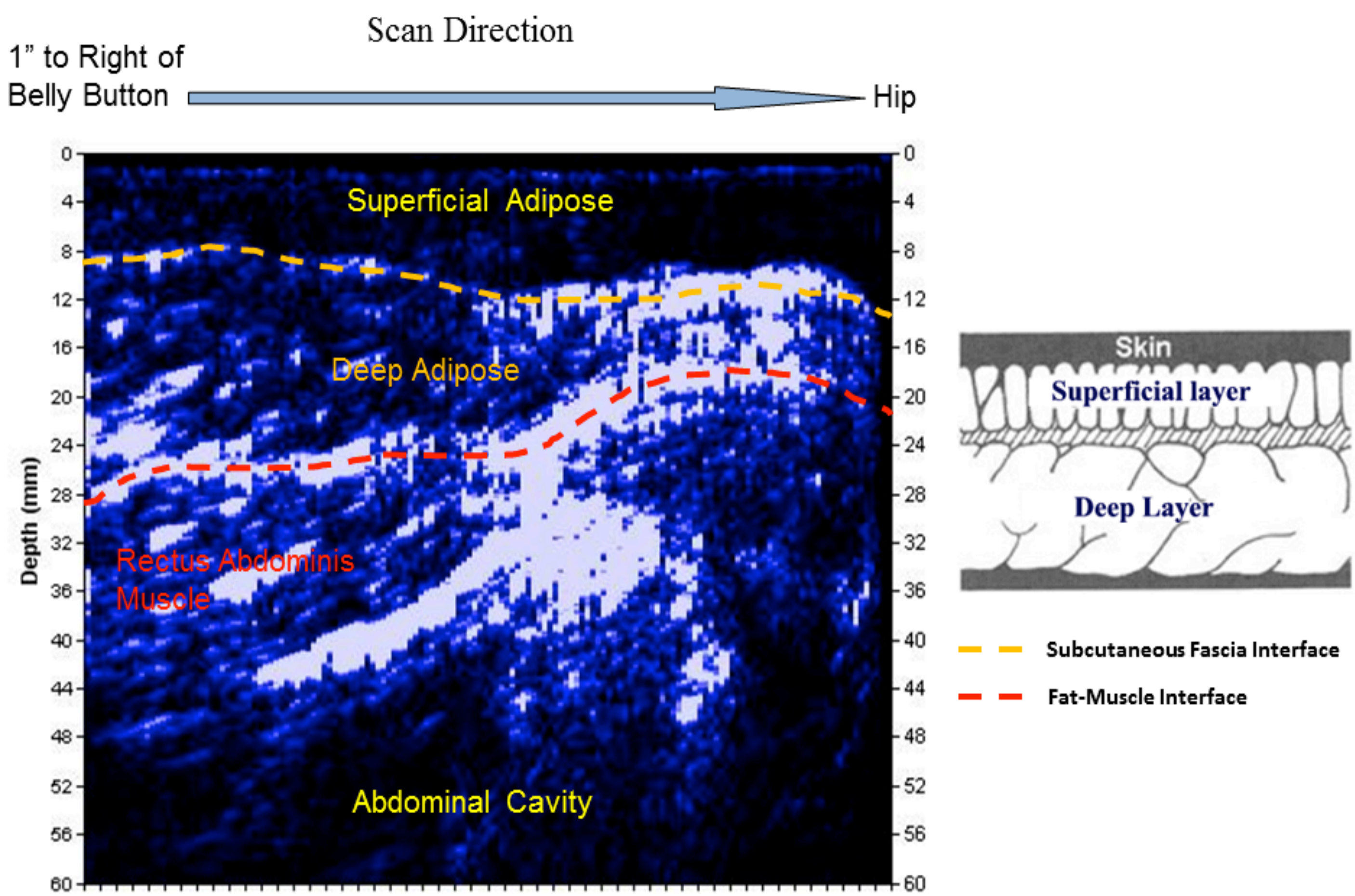

Figure 2 Waist scan of 50 year old male with 26% BF. The SAT and DAT layers are clearly visible.

“Skinny Fat” Waist Scan of Female

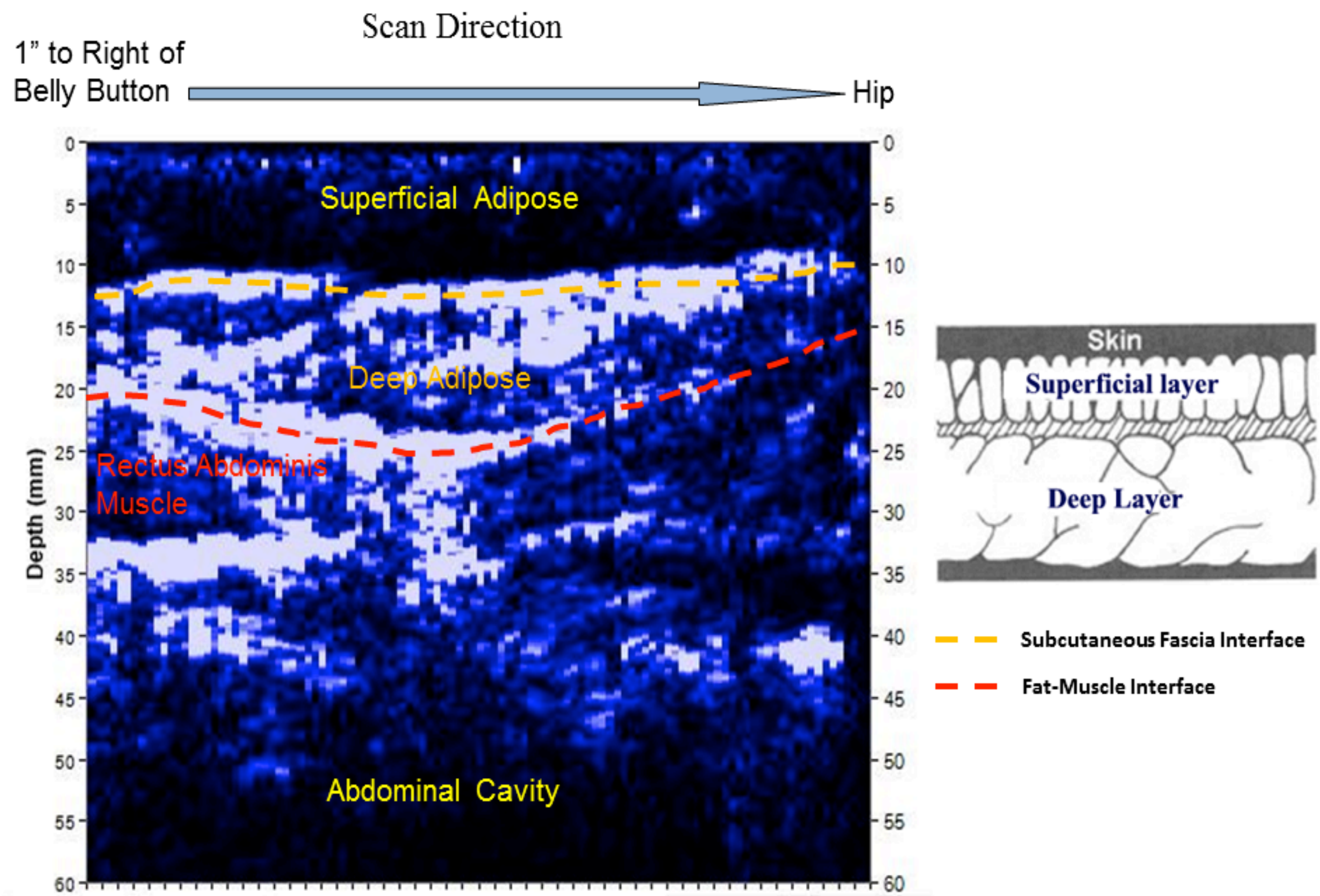

Figure 3 Waist scan of 22 year old female who visually appeared to be very fit. The scan indicates clear DAT. Her measured %BF= 25% which was higher than expected.

“Lean” Female Waist Scan

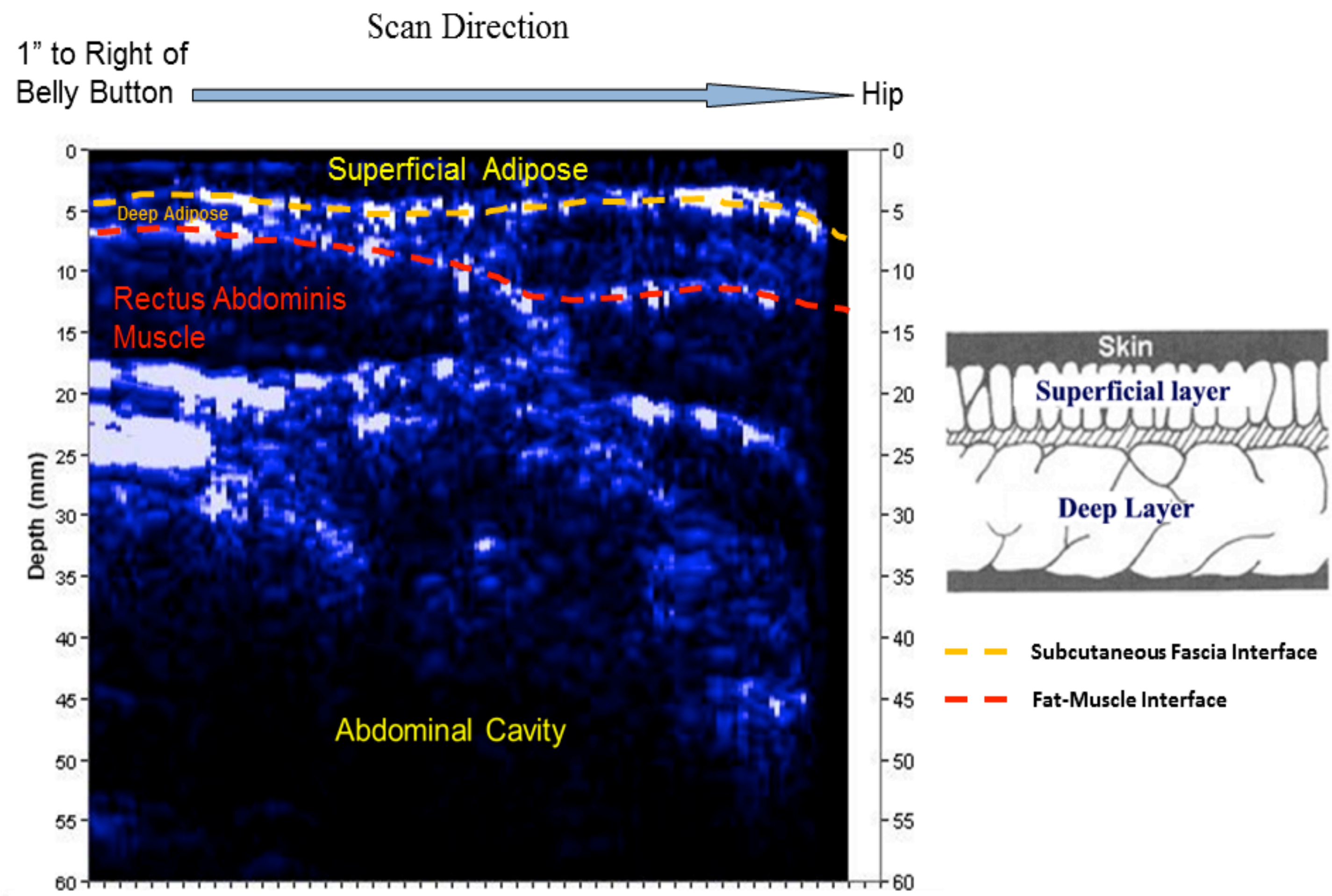

Figure 4 Waist scan of 18 year old female with 16% BF. Note how the fascia and muscle interfaces appear close together, indicating very little deep adipose tissue (DAT).

"Elite Lean Male" Waist Scan

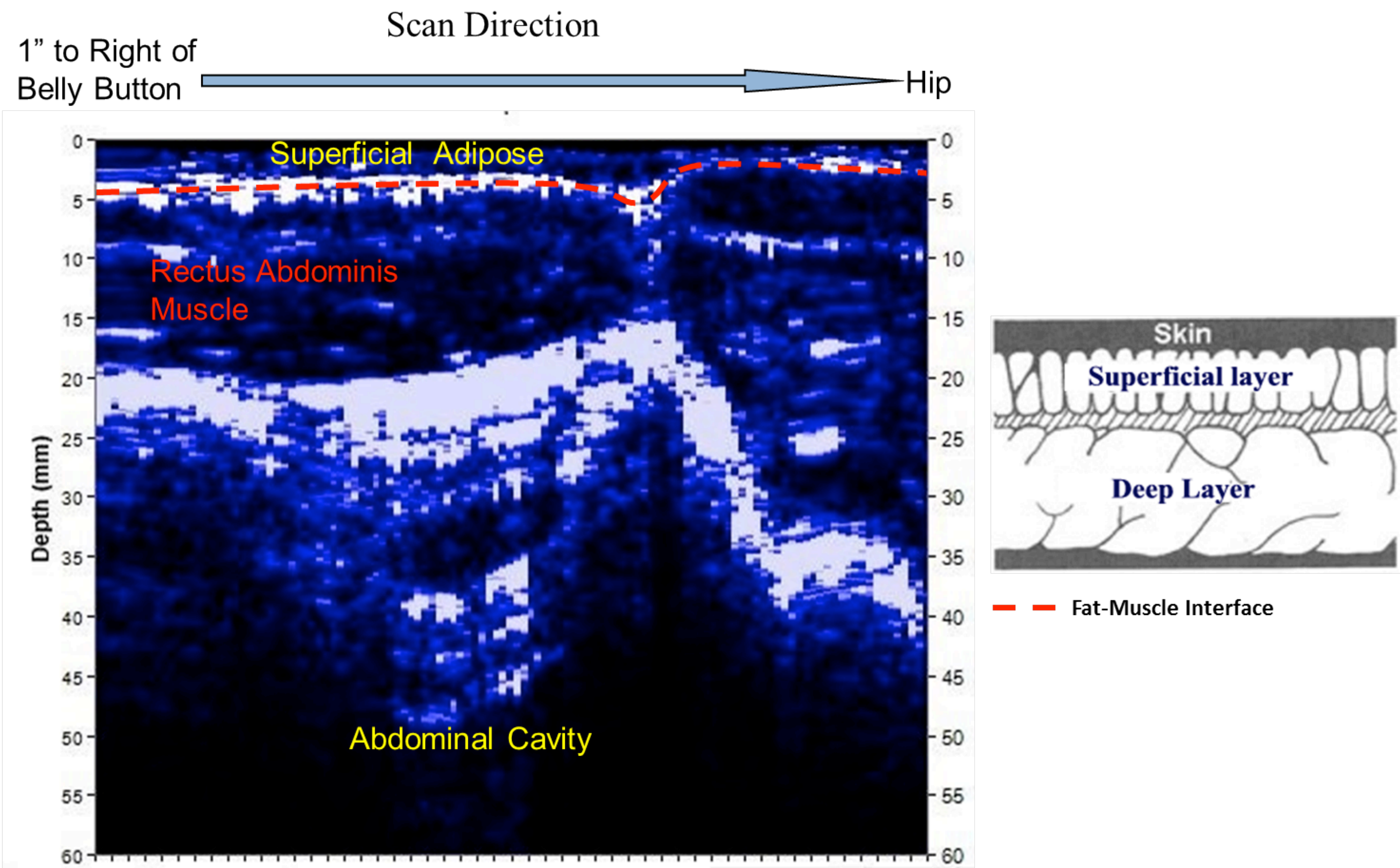

Figure 5 Waist scan of 21 year old elite male athlete with 3.5% BF. Note there is no evidence of deep adipose tissue (DAT).

“Elite Lean Female” Waist Scan

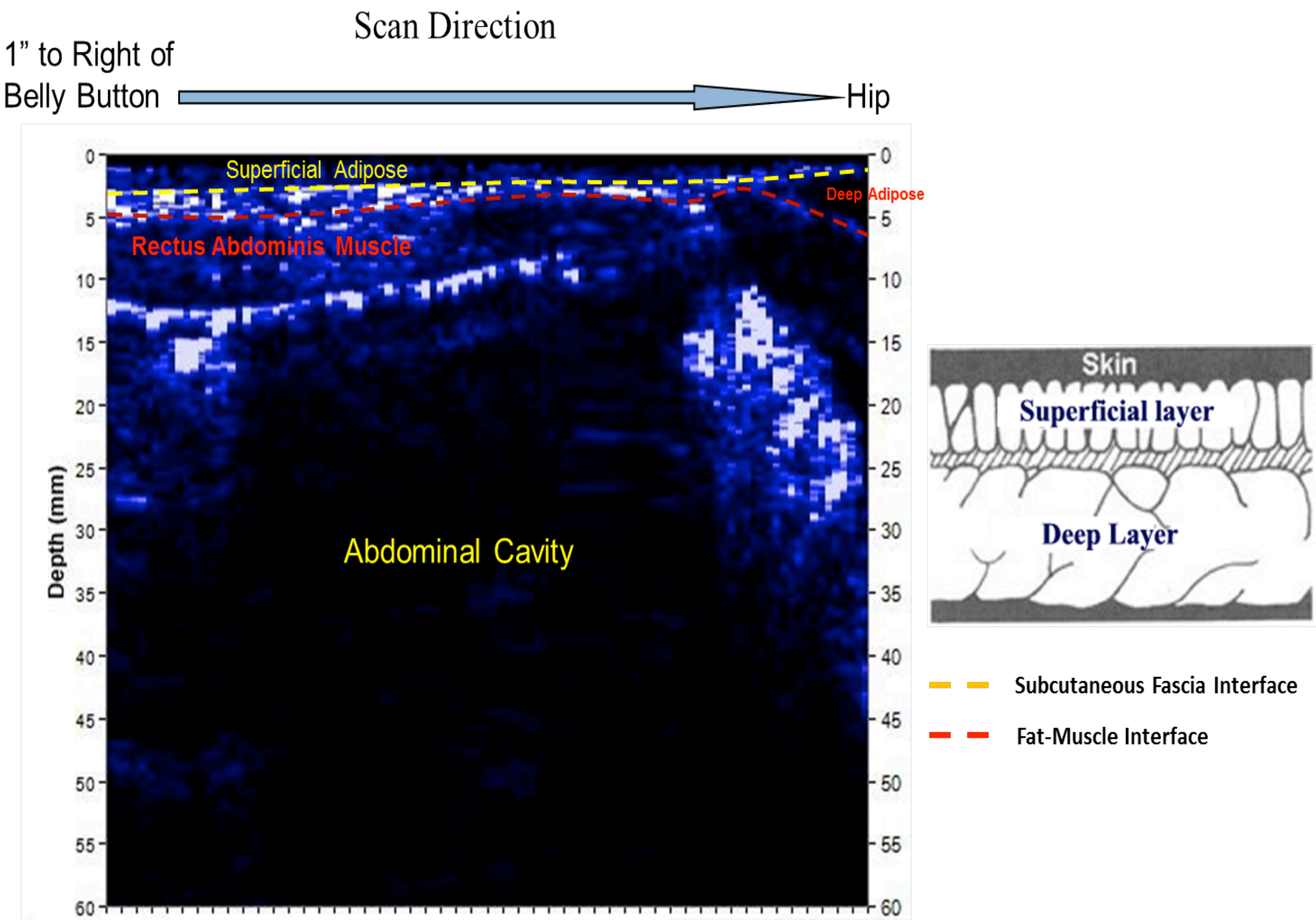

Figure 6 Waist scan of 23 year old elite female athlete with 12.7% BF. Note how the fascia and fat/muscle interfaces appear close together, indicating very little deep adipose tissue (DAT).

References

Aroone L.J. (2002a), *Classification of Obesity and Assessment of Obesity-Related Health Risks,* Obesity Research **10**, 105S-113S.

Aroone L.J., Segal K.R. (2002b), *Adiposity and Fat Distribution Outcome Measures: Assessment and Clinical Implications,* Obesity Research **10(S1)**, 14S-21S .

Black D., Vora J., Hayward M., and Marks R. (1988), *Measurement of subcutaneous fat thickness with high frequency pulsed ultrasound: comparisons with a caliper and a radiographic techniqueI,* Clin. Phys. Physiol. Meas. **9**, 57-64.

Brethour , J.R. (1994), *Estimating marbling score in live cattle from ultrasound images using pattern recognition and neural network procedures*, J. Anim. Sci **72**, 1425-32.

Carey, G.B. (1997), *The swine as a model for studying exercise induced changes in lipid metabolism.* Medicine and Science in Sports and Exercise **29**, 1437-43.

Chan JM, Rimm EB, Colditz GA, Stampfer MJ, Willett WC. (1994), *Obesity, fat distribution, and weight gain as risk 1actors for clinical diabetes in men.* Diabetes Care **17**,961-9.

Dempster P and Aitkens S (1995). *A new air displacement method for the determination of human body composition. Medicine and Science in Sports and Exercise.* **27**: 1692-1697.

Despres J-P, Lemieux I, Prud'homme D. (2001), Treatment of obesity: need to focus on high risk abdominally obese patients. BMJ **322,** 716-20.

Evans, W. (1997), *Functional and metabolic consequences of sarcopenia*, Journal of Nutrition **127**, 998S-1003S

Fields DA, Goran MI and McCrory MA (2002). *Body composition assessment via air-diaplacement plethysmography in adults and children: a review,* American Journal of Clinical Nutrition. **75,**453-467.

Goodpaster, B.H., Kelley, D.E., Wing, R.R., Meiier, A., and Thaete, F.L. (1999), *Effects of weight loss on regional fat distribution and insulin sensitivity in obesity,* diabetes **48**, 839-47.

Heymsfield, S.B., Lohman, T.G., Wang, Z, and Going, S.B., (2005), Human Body Composition (2nd Edition), United States: Human Kinetics.

Jackson, A. S., and Pollock, M. L. *Generalized equations for predicting body density of men. British Journal of Nutrition*, **40**, 497-504 (1978).

Jackson, A. S., and Pollock, M. L. (1985). *Practical assessment of body composition. The Physician and Sportsmedicine*, **13**, 76-90(1985).

Janessen, I., Heymsfield, S.B.,and Ross, R., *Low relative skeletal muscle mass (sarcopenia) in older persons is associated with functional impairment and physical disability*, Journal of the American Geriatric Society **50**, 889-96(2002).
Lee, W.-L., Chen Y.-C., Hsei K.-S. (2003), *Ultrasonic Liver Tissues Classification by Fractal Feature Vector Based on M-Band Wavelet Transform*, IEEE Transactions on Medical Imaging, **22**,382-392.

Monzon, J.R., Basile, R., Heneghan, S. Udupi, V., and Green, A. (2002), *Lipolysis in adipocityes isolated from deep and superficial subcutaneous adipose tissue*. Obesity Research **10**, 266-9.

Nordal, H.J., Dietrichson, P., Eldevick, P., and Gronseth, K. (1988), *Fat infiltration, atrophy and hypertrophy of skeletal muscles demonstrated by x-ray computed tomography in neurological patients*, Acta Neurologica Scandinavica **77**, 115-22.

Ohlson LO, Larsson B, Svardsudd K, Welin L, Eriksson H, Wilhelmsen L, et al. (1985) *The influence of body fat distribution on the incidence of diabetes mellitus. 13.5 years of follow-up of the participants in the study of men born in 1913*. Diabetes **34**,1055-8.

Pedro V.H., Pina F., Perez A., Tavares M., Barros H., (2004) *Visceral fat accumulation as a risk factor for prostate cancer,* Obesity Research **12**, 1930-1934.

Ribeiro-Filho F.F., Faria A.N., Azjen S., Zanella M.T., and Ferreira S.R.G. (2003), *Methods of Estimation of Visceral Fat: Advantages of Ultrasonography,* Obesity Research **11**, 1488-1494

Saito K., Nakaji S., Umeda T., Shimoyama T., Sugawara K. and Yamamoto Y. (2003), *Development of predictive equations for body density of sumo wrestlers using B-mode ultrasound for the determination of subcutaneous fat thickness,* Br. J. Sports Med. **37**, 144-148.

Tracy, B.L., Ivey, F.M., Hurlbut, D., Martel, G.F., Lemmer, J.T., Siegel, E.L., Metter, E.J., Fozard, J.L., Fleg, J.L., and Hurley, B.F. (1999) , *Muscle Quality II. Effects of strength training in 65 to 75 yr old men and women*, Journal of Applied Physiology **86**, 195-201.

Unser M., and Aldroubi A. (1996), *A Review of Wavelets in Biomedical Applications*, Proceedings of the IEEE, **84**, 626-638.

Wajchenberg, B.L. (2000), *Subcutaneous and visceral adipose tissue: their relation to the metabolic syndrome.* Endocr. Rev. **21**, 697-738.

Wilson, D., Zhang H., Rouse G.H., Izquierdo M.M., Duello D.D., and Hinz P.N., *using real-time ultrasound to predict intramuscular fat in the longissimus dorsi of live beef animals,* Iowa State Univ. Sci. Leaflet **R1017**, Ames.