

Technical Considerations in Advanced Clinical Body Composition Evaluation

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Overview

Dual energy x-ray absorptiometry (DXA) body composition measurements are increasingly utilized in the evaluation of clinical obesity,^{1,2} muscle loss and wasting (sarcopenia),³ and abnormal patterns of fat distribution (lipodystrophy).⁴ Obesity is widely recognized as a major risk factor for type 2 diabetes, metabolic syndrome, and cardiovascular disease.⁵ Sarcopenia has been shown to be highly predictive of functional disability in the elderly,⁶ and lipodystrophy is a major complication of antiretroviral treatments.⁷ In addition to detecting abnormalities in body composition, DXA is also employed to evaluate the effects of diet and exercise in health clinics^{8, 9} and physical training in athletes and military recruits.¹⁰

Clinical Management: Weight Loss Intervention

The data below were obtained from a diet and exercise weight loss intervention. Serial measurements of Fat Mass Index (FMI: Fat Mass/Height²) are plotted over time (Figure 1). Note the drastic reduction in FMI from above the median value for the subject's age, ethnicity, and gender to well below the median occurring over a period of about six months. The compartmental trending plot shows striking decreases in the fat mass compartment and relatively minor declines in the

lean mass compartment during the intervention (Figure 2). The color image mapping of these trends displayed in the serial whole body images provides positive patient feedback and may be useful as a counseling tool. The images reveal a loss of nearly pure subcutaneous and visceral fat (light orange) over time (Figure 3).

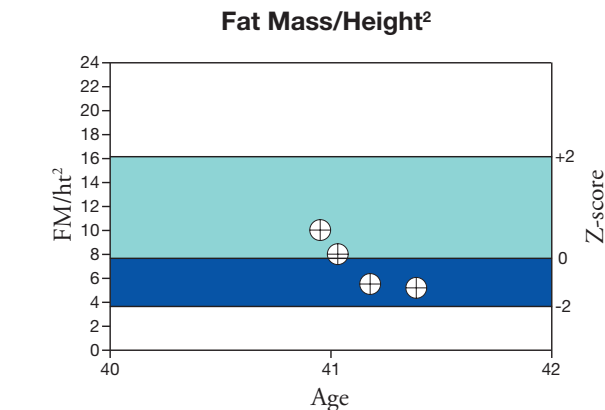


Figure 1. Serial measurements of FMI plotted over time.

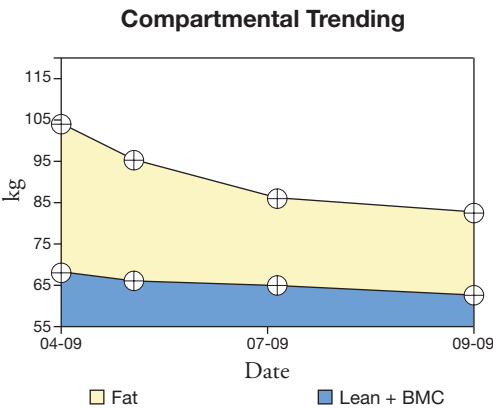


Figure 2. The compartmental trending plot shows striking decreases in the fat mass compartment. Lean mass decreased initially (loss of water) and then remained relatively stable.

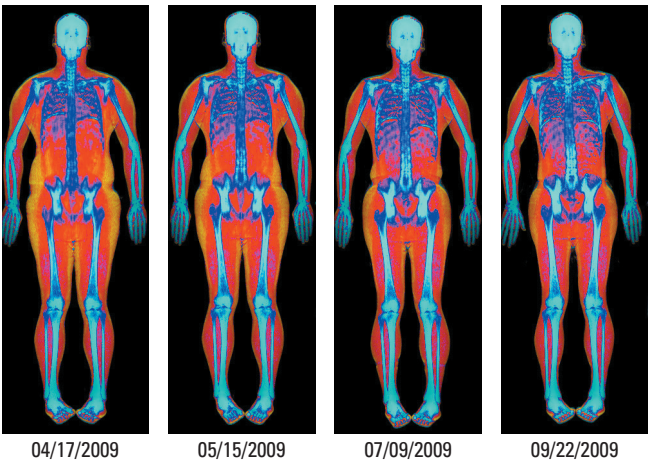


Figure 3. Color image mapping of serial whole body images may be useful as a counseling tool.

Diagnostic Information and Reference Data

Diagnostic information is obtained by direct comparison to a gender- and ethnicity-specific reference data developed from the National Health and Nutrition Examination Survey (NHANES) data released on the Centers for Disease Control and Prevention (CDC) website and contains over 20,000 subjects aged 8 to 85 (Figure 4). The NHANES body composition reference database represents one of the largest peer-reviewed studies ever undertaken and assures reliable Z-scores and percentiles for all body composition measures.¹¹ The International Society for Clinical Densitometry (ISCD) has already adopted the NHANES Hip reference database

for all DXA scanners¹² and is considering standardization utilizing the NHANES body composition database. Reference data were modeled using the LMS curve fitting procedure¹³ because it handles skewness and many body composition measurements are not normally distributed. When skewness is present, the concept of a standard deviation does not apply in the usual sense, and accurate Z-scores and percentiles are not possible without an adjustment for skewness (Figure 5). For these reasons, competitive DXA systems that do not account for skewness may generate inaccurate and or unreliable diagnostic scores.

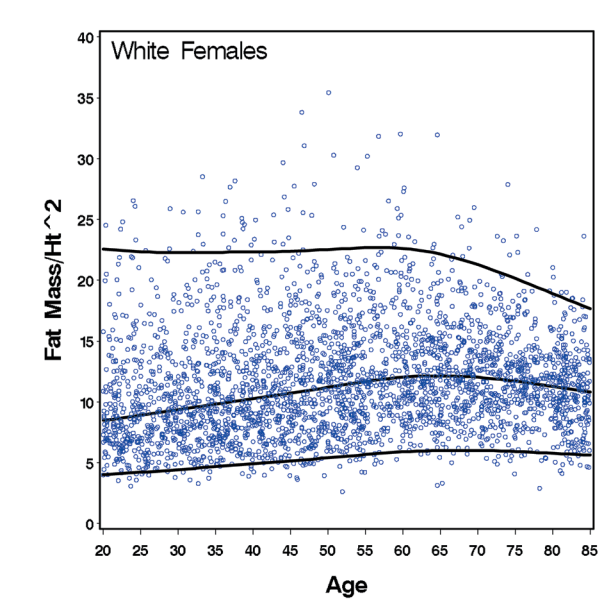


Figure 4. Gender and ethnicity specific FMI reference data in white females developed from the NHANES reference database containing over 20,000 subjects aged 8 to 85.

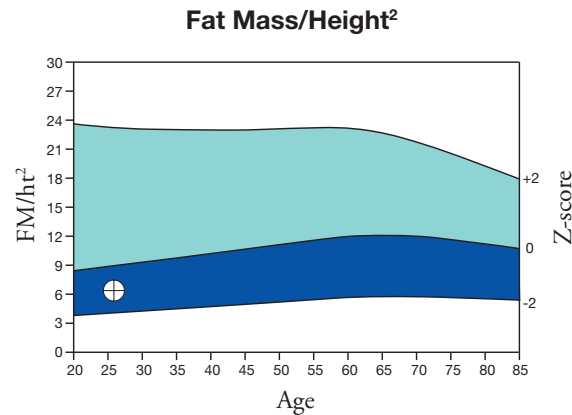


Figure 5. FMI reference curve in white females showing the effect of skewness. Note the difference in the area above the median value (light blue region) and below the median value (dark blue region). Accurate diagnostic scores are not possible unless an adjustment for skewness (unequal distributions about the median value) is performed.

FMI Class	Severe Fat Deficit	Moderate Fat Deficit	Mild Fat Deficit	Normal	Excess Fat	Obese Class I	Obese Class II	Obese Class III
M	< 2	2 to < 2.3	2.3 to < 3	3 – 6	> 6 to 9	> 9 to 12	> 12 to 15	> 15
F	< 3.5	3.5 to < 4	4 to < 5	5 – 9	> 9 to 13	> 13 to 17	> 17 to 21	> 21

Table 1. Classification ranges for FMI that match the prevalences of the World Health Organization (WHO) body mass index (BMI) classifications in young adults. Unlike BMI (a measure of excess weight), FMI is a gender specific measure of excess fat not confounded by lean tissue.

Obesity Diagnosis and Classification

All Discovery™ systems support an obesity classification scheme that matches the prevalences of well established BMI classification thresholds and generates similar thresholds for FMI.¹¹ The prevalence-matched FMI classifications shown in Table 1 should offer superior specificity because, unlike BMI, the index is based on fat mass, not body weight, which is composed of both fat and lean constituents.

Sarcopenia

Sarcopenia is defined as a degenerative loss of skeletal muscle mass and strength. Diagnosis is based on a DXA appendicular lean mass/height² of more than two standard deviations below the young normal mean, or about 7.0 kg/m² for men and 5.25 kg/m² for women.³

Clinical Body Composition Report

Discovery advanced clinical reports provide information on fat and lean mass indices that are useful in the assessment and management of a wide variety of abnormalities including clinical obesity, abdominal obesity, lipodystrophy, and sarcopenia. Diagnostic scores from the NHANES database are provided as T-scores, Z-scores and percentiles (Figure 6).

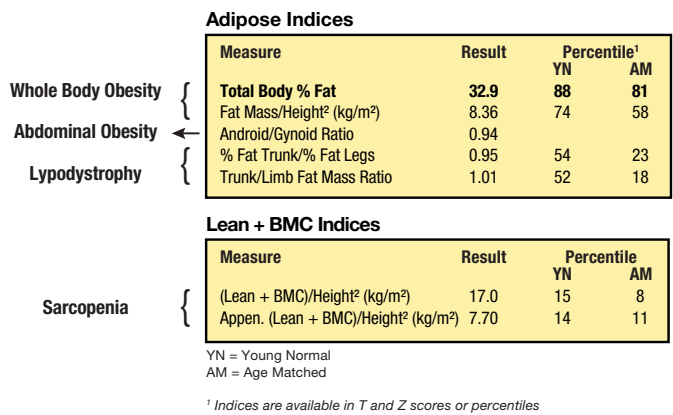


Figure 6. Advanced Body Composition™ assessment report. Adipose and Lean indices with typical clinical applications.

Calibration and Accuracy

Clinical medicine and research demand measurement systems with accurate results and reliable diagnostic information. Discovery body composition results are calibrated to a large (n=1,155 subjects) multi-center study between DXA and other criterion methods, including deuterium dilution, hydrostatic weighing, and four-compartment models.¹⁴ This is the most comprehensive and definitive DXA calibration study ever performed and provides the foundation for all direct and derivative body composition measurements provided by Discovery whole body scanners.

Summary and Conclusion

The role of body composition measurements is expanding into many areas of clinical medicine and research. Accurate and reliable results and diagnostic information are critical to proper patient management and can only be obtained on properly calibrated instruments utilizing the most comprehensive reference database. The Discovery Advanced Body Composition assessment and report fully satisfy these requirements and set the industry standard against which DXA instruments are measured.

Hologic scientists continue to advance the field of body composition research in order to provide improved clinical measures. Hologic recently patented methods for measuring visceral fat using DXA.¹⁵ Visceral fat is a metabolically active pathogenic fat depot^{16, 17} that may predispose to serious health risks including cardiovascular disease. These enhancements will keep Discovery body composition applications on the forefront of clinical medicine and research for years to come.

References

¹ K. Davison, S. Bircher, A. Hill, A.M. Coates, P.R. Howe and J.D. Buckley, "Relationships between Obesity, Cardiorespiratory Fitness, and Cardiovascular Function," *J Obes*, 2010 191253.

² P. Katz, S. Gregorich, J. Yazdany, L. Trupin, L. Julian, E. Yelin and L.A. Criswell, "Obesity and its measurement in a community-based sample of women with systemic lupus erythematosus," *Arthritis Care Res (Hoboken)*, 63 261-8.

³ A.J. Cruz-Jentoft, J.P. Baeyens, J.M. Bauer, Y. Boirie, T. Cederholm, F. Landi, F.C. Martin, J.P. Michel, Y. Rolland, S.M. Schneider, E. Topinkova, M. Vandewoude and M. Zamboni, "Sarcopenia: European consensus on definition and diagnosis: Report of the European Working Group on Sarcopenia in Older People," *Age Ageing*, 39 412-23.

⁴ E. Bonnet, C. Delpierre, A. Sommet, F. Marion-Latard, R. Herve, C. Aquilina, E. Labau, M. Obadia, B. Marchou, P. Massip, B. Perret- and J. Bernard, "Total body composition by DXA of 241 HIV-negative men and 162 HIV-infected men: proposal of reference values for defining lipodystrophy," *J Clin Densitom*, 8 (2005), 287-92.

⁵ S.C. Smith, Jr., "Multiple risk factors for cardiovascular disease and diabetes mellitus," *Am J Med*, 120 (2007), S3-S11.-

⁶ R.N. Baumgartner, K.M. Koehler, D. Gallagher, L. Romero, S.B. Heymsfield, R.R. Ross, P.J. Garry and R.D. Lindeman, "Epidemiology of sarcopenia among the elderly in New Mexico," *Am J Epidemiol*, 147 (1998), 755-63.

⁷ M. Law, R. Puls, A.K. Cheng, D.A. Cooper and A. Carr, "Evaluation of the HIV lipodystrophy case definition in a placebo-controlled, 144-week study in antiretroviral-naïve adults," *Antivir Ther*, 11 (2006), 179-86.

⁸ A.R. Josse, J.E. Tang, M.A. Tarnopolsky and S.M. Phillips, "Body composition and strength changes in women with milk and resistance exercise," *Med Sci Sports Exerc*, 42 1122-30.

⁹ A.R. Josse, S.A. Atkinson, M.A. Tarnopolsky and S.M. Phillips, "Increased consumption of dairy foods and protein during diet- and exercise-induced weight loss promotes fat mass loss and lean mass gain in overweight and obese premenopausal women," *J Nutr*, 141 1626-34.

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- ¹⁰ M. Malavolti, N.C. Battistini, M. Dugoni, B. Bagni, I. Bagni and A. Pietrobelli, "Effect of intense military training on body composition," *J Strength Cond Res*, 22 (2008), 503-8.
- ¹¹ T.L. Kelly, K.E. Wilson and S.B. Heymsfield, "Dual energy X-Ray absorptiometry body composition reference values from NHANES," *PLoS One*, 4 (2009), e7038.
- ¹² D. Hans, R.W. Downs, Jr., F. Duboeuf, S. Greenspan, L.G. Jankowski, G.M. Kiebzak and S.M. Petak, "Skeletal sites for osteoporosis diagnosis: the 2005 ISCD Official Positions," *J Clin Densitom*, 9 (2006), 15-21.
- ¹³ T.J. Cole, "The LMS method for constructing normalized growth standards," *Eur J Clin Nutr*, 44 (1990), 45-60.
- ¹⁴ D.A. Schoeller, F.A. Tylavsky, D.J. Baer, W.C. Chumlea, C.P. Earthman, T. Fuerst, T.B. Harris, S.B. Heymsfield, M. Horlick, T.G. Lohman, H.C. Lukaski, J. Shepherd, R.M. Siervogel and L.G. Borrud, "QDR 4500A dual-energy X-ray absorptiometer underestimates fat mass in comparison with criterion methods in adults," *Am J Clin Nutr*, 81 (2005), 1018-25.
- ¹⁵ T.L. Kelly, Estimating visceral fat by dual-energy absorptiometry. Patent # 7,725,153 (U.S.: Hologic, Inc., 2011).
- ¹⁶ J.L. Kuk, P.T. Katzmarzyk, M.Z. Nichaman, T.S. Church, S.N. Blair and R. Ross, "Visceral fat is an independent predictor of all-cause mortality in men," *Obesity (Silver Spring)*, 14 (2006), 336-41.
- ¹⁷ C.S. Fox, J.M. Massaro, U. Hoffmann, K.M. Pou, P. Maurovich-Horvat, C.Y. Liu, R.S. Vasan, J.M. Murabito, J.B. Meigs, L.A. Cupples, R.B. D'Agostino, Sr. and C.J. O'Donnell, "Abdominal visceral and subcutaneous adipose tissue compartments: association with metabolic risk factors in the Framingham Heart Study," *Circulation*, 116 (2007), 39-48.

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