Journal of Clinical Densitometry: Assessment & Management of Musculoskeletal Health, vol. 16, no. 4, 496–507, 2013
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1094-6950/16:496–507/$36.00
http://dx.doi.org/10.1016/j.jocd.2013.08.020

2013 Position Development Conference on Bone Densitometry

The Official Positions of the International Society for Clinical Densitometry: Indications of Use and Reporting of DXA for Body Composition

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Abstract

The technique of body composition by dual-energy X-ray absorptiometry (DXA) has been used for several years in the research environment. Its ability to accurately and precisely measure lean, fat, and mineral composition in various body compartments has been well validated. Furthermore, the technique is widely available to clinical patients on existing DXA instruments throughout the world through the use of specific software packages and scanning algorithms. There have been few clear statements regarding the clinical indications for body composition measurement in patients outside the research setting. This is in part because of the lack of specific documented interventions that would be affected by body composition test results, beyond usual clinical advice. We have examined a few of the most common, specific scenarios (HIV therapy, sarcopenia, bariatric surgery, obesity) and proposed indications for body composition assessment. We have also discussed contraindications to body composition testing.

Key Words: Body composition; DXA; obesity; sarcopenia.

Introduction

The task force addressed questions related to the clinical indications for body composition testing that could be supported by the published literature. Specific areas of focus were indications for body composition testing in persons living with HIV, patients after bariatric surgery, obese patients, anorexia, and sarcopenia. In addition, we searched the literature on other techniques for estimating body composition and contraindications to dual-energy X-ray absorptiometry (DXA) body composition testing. The references obtained were augmented by other pertinent references known by committee members but not appearing in the search strategy. Appendix lists the search terms used and the citations obtained. Relevant publications were downloaded and reviewed; the results collated in a data table. Presentations to the expert panel were formulated from this. The final positions agreed on by the expert panel were then brought into the document with the references supporting the final official positions.

Using DXA technology for body composition analysis has the potential to offer new diagnostic insights for patient disease in a variety of areas. In addition, the technology has

Received 08/16/13; Accepted 08/20/13.
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the potential to monitor change with therapy or other interventions. Other technologies that measure body composition include computed tomography (CT), magnetic resonance imaging (MRI), bioelectrical impedance analysis (BIA), air/water displacement, and anthropometric measurements. Each of these techniques has unique strengths and limitations, with trade-offs in ease of use, accessibility, accuracy, and comprehensiveness. DXA is well correlated with CT, MRI, and BIA *(1–6)* and should be considered when quantitative body composition measurement is desired *(7–9)*. In some instances, use of body composition technologies other than DXA may be superior *(2,10)*. For example, CT and MRI offer more detailed measurements of specific regions or tissues, such as visceral adipose fat or fat infiltration of tissues *(8,9)*. Although most DXA software will allow for an estimate of visceral adipose tissue, the level of detail is inferior to that of CT or MRI *(11,12)*. Nevertheless, DXA may be preferred as the whole body may be easily quantified, radiation exposure is low, and it is likely to be more accessible and more economical to obtain than CT or MRI *(1,7,8)*. As noted earlier, BIA is also widely available for body composition assessment; its advantage over DXA is portability, device cost, and ease of administration *(8)*. Although less portable, air and water displacement systems generate similar measurements using a different technique *(13)*. However, the inability of these methods to independently obtain measurement of more than fat or fat-free mass limits their utility. More recent versions of BIA technology have improved ability to assess regions and differentiate inter- and intracellular water *(14,15)*. In general, anthropometric methods are useful to assess cardiovascular disease and diabetes risk *(16)* and are considered crude tools to assess body composition. The strengths and limitations of these technologies are summarized in Table 1.

As DXA is demonstrated to be a viable method to measure body composition, it was deemed appropriate to address the lack of consistent guidelines recommending indications for DXA body composition and for standardized reporting of these measurements. In this endeavor, the lack of well-designed comparative studies of the modalities described earlier is acknowledged as noted in the evidence and strength of recommendation grades associated with these positions. Although there are good data validating and correlating the tools, there are no head-to-head studies evaluating comparability in a specific circumstance. Consequently, in many cases, the guidelines presented in this work will be based on clinical research studies from small numbers of patients and often lack endpoint validation or cost-efficacy data.

The task force was charged with developing recommendations for several conditions and diseases where body composition analysis by DXA may prove valuable. These conditions include people living with HIV, obesity, postbariatric surgery or weight loss, and sarcopenia. Performance athletes may benefit from applications of body composition analysis by DXA as an aid to training, but this has been addressed by others *(17)* and, consequently, was not addressed by this group.

What Are the Clinical Indications of Using DXA for Patients With HIV?

ISCD Official Position

- DXA total body composition with regional analysis can be used in the following conditions: in patients living with HIV to assess fat distribution in those using antiretroviral agents associated with a risk of lipoatrophy (currently stavudine and zidovudine).
  Grade: Good-B-W

Rationale

"HIV lipodystrophy" is a term that is used to describe alterations in fat distribution that became apparent early in the era of life-extending highly active antiretroviral therapy. Although there is no consensus definition, the term most commonly refers to lipoatrophy (subcutaneous fat loss in the arms, legs, face, abdominal region), with or without concomitant central fat accumulation (increased visceral fat, buffalo hump, lipomata). Less commonly, the term HIV lipodystrophy is also applied to obesity with excess visceral adiposity in the absence of lipoatrophy. HIV researchers have exploited the ability of DXA to perform regional body composition analysis to pinpoint the independent effects of antiretroviral agents on peripheral (arm and leg) and central (trunk) fat in

Table 1
Strengths and Limitations of Modalities to Measure Body Composition

Measurement technology	Cost/time	Radiation	Accuracy	Precision	Regional	Lean/bone	Intratissue fat
DXA	S	S	S	S	S	S	L
CT	L	L	S	S	S	S	S
MRI	L	S	S	S	S	S	S
BIA/BIS	S	S	L	S	L	L	L
Air/water displacement	S	S	S	L	L	L	L
Anthropometric	S	S	L	L	L	L	L

Adapted from published descriptions *(7–9,16)*.
Abbr: CT, computed tomography; DXA, dual-energy X-ray absorptiometry; L, limitations; MRI, magnetic resonance imaging; S, strenghts.

numerous randomized multicenter trials of treatment initiation (18–23) and studies in persons on therapy in which 1 antiretroviral agent was substituted for another (24–30) or discontinued (31) or added (32). In many of these studies, use of DXA allowed investigators to detect statistically significant changes in peripheral fat before they became clinically evident. As a result, researchers were able to identify the individual agents most responsible for peripheral lipoatrophy (stavudine and zidovudine). As discussed subsequently, the role of other antiretroviral agents in potentially contributing to lipoatrophy is less clear. Because of their effect on peripheral fat and other toxicities (33) and the availability of alternative agents considered less toxic, stavudine and zidovudine are no longer a part of first-line treatment regimens, and most people with HIV who had been using them have switched to other treatments. Thus, routine DXA monitoring of body composition in all HIV-infected persons on treatment is not warranted. However, inclusion of DXA in trials of new agents is necessary to identify unexpected toxicities of these drugs and to establish their regional effects on fat and fat distribution. Moreover, DXA monitoring may be useful in persons who remain on regimens containing agents shown to promote lipoatrophy (34). The etiology of increases in central fat is less well defined as is the ability of DXA to assess changes in central fat, as changes in central fat may include both increases in visceral fat and decreases in subcutaneous fat. Accordingly, most treatment initiation and switch studies use other imaging technology (CT or MRI) to measure changes in abdominal fat (22,24,31,32). Accordingly, DXA monitoring of changes in trunk fat in people with HIV infection is not currently warranted.

DXA body composition with regional analysis has also been used to evaluate the efficacy and potential toxicity of pharmacologic agents used to treat the physical features of HIV lipodystrophy in numerous randomized multicenter studies in which peripheral fat by DXA was the primary or a key secondary outcome. These include trials of the growth hormone–releasing hormone tesamorelin, which is approved by the Food and Drug Administration as a treatment for HIV-associated visceral fat accumulation (35,36), pharmacologic doses of growth hormone, a potent lipolytic agent that not only reduced visceral fat but also accelerated peripheral fat loss (37–39), thiazolidinediones, which either increased or had no effect on peripheral fat (39–44), and metformin, which caused general fat loss (42,45), among others (39,46,47). As is the case with studies of antiretroviral agents, DXA has been successfully applied to detect changes in peripheral fat, but CT has been employed to assess changes in central fat (36–40,42,43,45–47). Thus, DXA may be warranted for monitoring the effects of long-term use of any of these treatments on peripheral fat; newer DXA software capable of analyzing visceral fat may be required to monitor central fat changes.

Discussion

DXA with central regional analysis has proven to be a highly sensitive and consistently reliable technique for detecting changes in regional fat distribution over relatively short periods (e.g., 6 mo to 1 yr) before clinically apparent lipodystrophy develops (48,49) or reverses (30). Early cross-sectional studies that initially described the syndrome in both adults and children (50–55) led to a proposed case definition (56). The studies also used DXA to show differences in regional composition distinguishing those with the physical features of the syndrome from seronegative controls of HIV-infected persons without evidence of alterations in fat distribution.

The 2 main classes of antiretroviral agents that have been associated with lipodystrophy are nucleoside reverse transcriptase inhibitors (NRTIs), particularly thymidine analogue NRTIs stavudine and zidovudine, which are directly linked to peripheral lipoatrophy and, to a less clear extent, some protease inhibitors, which in some studies appear to accelerate the development of lipodystrophy (21). A role for the third major class of antiretrovirals, non-NRTI, especially efavirenz, is unclear, with limited evidence of a permissive or accelerating effect of efavirenz. Newer classes of antiretrovirals, including integrase inhibitors, fusion inhibitors, and CCR5 antagonists, have not as yet been associated with alterations in fat distribution. Increases in trunk fat have been reported with regimens containing efavirenz, protease inhibitors, and the integrase inhibitor raltegravir, but a causal relationship has not been established. Most HIV-infected persons on the most toxic agents could be or already have been switched to other agents that have a lower risk of lipodystrophy and lipoatrophy.

Additional Questions for Future Research

DXA body composition techniques for evaluating intra-abdominal and subcutaneous abdominal fat could be substituted for CT or MRI imaging studies that are often required to evaluate changes in central fat. Longitudinal studies of DXA in patients on various antiretroviral therapies and therapies prescribed to alter fat distribution in HIV would be useful:

i. new antiretroviral agents for HIV should be evaluated for risk of lipodystrophy (both lipoatrophy and central fat accumulation) in controlled studies using DXA body composition with regional analysis.
ii. interventions designed to treat the physical features of lipodystrophy (e.g., growth hormone–like products, insulin sensitizing agents) should be evaluated for their effects on peripheral fat using DXA body composition with regional analysis.

What Are the Clinical Indications of Using DXA for Patients Either Considering or Having Recently Had Bariatric Surgery?

ISCD Official Position

- DXA total body composition with regional analysis can be used in the following conditions: in obese patients undergoing bariatric surgery (or medical, diet, or weight loss

regimens with anticipated large weight loss) to assess fat and lean mass changes when weight loss exceeds approximately 10%. The impact on clinical outcomes is uncertain.
Grade: Poor-C-W

Rationale

Most of our currently available weight loss methods induce unintended loss of lean mass in addition to desirable fat mass reduction (57–59). Men may be more susceptible than women to lean mass decline with weight loss (57). There is particular concern that bariatric surgery is associated with a higher proportion of lean mass loss than nonsurgical methods of weight loss (57,60). Some longitudinal studies documented that bariatric surgery leads to a 30%–50% decrease in fat mass and a 10%–15% decline in lean mass at 1 yr (1,61–67). Lean mass loss after bariatric surgery occurs primarily within the first 3–6 mo (62–65,68). This may be related to bariatric surgery type, with less pronounced lean mass loss after purely restrictive procedures such as gastric banding (68–73), compared with mixed restrictive/malabsorptive procedures such as Roux-en-Y gastric bypass and biliopancreatic diversion (1,61–67).

In these situations, serial DXA measurements of body composition may be useful to identify those patients who may benefit from additional interventions to mitigate loss of lean mass. Randomized controlled trials suggest that lean mass declines during nonsurgical weight loss may be attenuated by exercise and dietary interventions (74–79). Fewer published studies regarding the efficacy of exercise interventions in patients after bariatric surgery exist. One observational study noted that higher self-reported physical activity after gastric bypass was associated with decreased lean mass loss (61). There are also few data published on the efficacy of dietary interventions to prevent lean mass loss in this population. One observational study suggested that protein intake greater than 60 g/d was associated with lower lean mass decline (64), but a randomized controlled trial of an amino acid nutritional supplement found no effect in attenuating lean mass loss 8 wk after gastric bypass (62).

Longitudinal studies suggest that bariatric surgery also may be accompanied by whole-body bone density loss (66,80–82). However, most of this loss appears to occur at axial sites and is, therefore, best assessed with dedicated DXA hip and spine measurements (66,80–82). Indeed, World Health Organization diagnostic criteria for osteoporosis in postmenopausal women are only from hip, spine, and one-third radius sites (83).

In situations where large magnitude weight loss is anticipated, such as after bariatric surgery, it is helpful to obtain baseline DXA body composition to monitor lean and fat (or regional fat) mass changes. Repeat scans can be obtained at 3 mo after bariatric surgery or when nonsurgical weight loss exceeds approximately 10%. Early detection of lean mass decline during weight loss may prompt clinical recommendations for exercise and dietary modifications to prevent further reduction in lean mass and physical function.

Discussion

There are important practical considerations that limit the use of DXA body composition testing in severely obese patients. First, the clinician must be mindful of table weight limits, which vary from 350 pounds in older models to 450 pounds in newer models. Second, obese patients may have a body habitus that exceeds the scan area for the whole-body scan, in which case "offset scanning" may be required (see "Acquisition of DXA body composition measures in patients" for further discussion of these 2 issues). Lastly, DXA body composition and bone mass measurements may be susceptible to obesity-related imaging artifact from soft tissue excess (84–87). Therefore, it is possible that reduced soft tissue thickness associated with large weight loss may negatively affect the accuracy and precision of DXA body composition results.

Additional Questions for Future Research

Interventional trials should be performed in the bariatric surgery population to determine whether exercise or dietary modifications mitigate the loss of lean body mass. Additional research is also needed to better define how soft tissue changes affect the reliability of DXA body composition measurements before and after large magnitude weight loss.

What Are the Clinical Indications of Using DXA for Patients With Sarcopenia?

ISCD Official Position

- DXA total body composition with regional analysis can be used in the following conditions: in patients with muscle weakness or poor physical functioning to assess fat and lean mass. The impact on clinical outcomes is uncertain.
  Grade: Fair-C-W

Rationale

Although there is an association between sarcopenia and decreased functional capacity, a diagnosis of pathologic sarcopenia must certainly rely on a combination of muscle measurements and functional measurements. Functional capacity is traditionally assessed by grip strength, quadriceps strength, gait speed measurement, and get up and go test. However, functional tests might be altered by reasons different from muscle loss, such as medications affecting the central nervous system, depression, poor mental status, malnutrition, and neuropathy. DXA assessment of lean mass is highly reproducible and can individualize patient monitoring independently of external comorbidities. Therefore, a combination of DXA and functional tests may optimize strategies for improving a patient's functional status (88).

Sarcopenic/obese men and women do not display lower physical capacity compared with nonsarcopenic/obese individuals in a cohort of well-functioning older men and women. Obesity per se appears to contribute more to lower physical capacity than sarcopenia when patients do not show poor

functioning (89). In another cohort, it was found that sarcopenia is negatively associated with walking. These findings support the need to first determine a low level of physical performance before evaluating DXA assessment of low lean mass (88). Recent data from the Framingham study report that low appendicular lean mass normalized to body size and/or fat mass is independently associated with self-reported mobility limitations in addition to the strong but separate independent effect of increased fat mass (90).

Gait speed and grip strength are correlated, and both have been used as surrogates for the assessment of muscle strength. Using consensus definitions, sarcopenia was found to be infrequent among older home-dwelling women. Thus, attention should be paid to the decline in functional ability rather than focusing on low muscle mass alone (91).

Evaluation of DXA body composition and dynamometer quadriceps strength demonstrated that higher fatness was associated with lower lean mass quality (92). Body fat to muscle ratio could predict incident or worsening physical limitation in both sexes. The parameters used were total body fat to lower limb muscle mass, total body fat to fat-free mass, and body weight to fat-free mass. Functional status was assessed by Mini-Mental Status and Geriatric Depression Score. This prediction was consistent in obstructive pulmonary disease, diabetes mellitus, hypertension, heart disease, and stroke (93). Insulin resistance accelerated age-related sarcopenia when lean body mass was measured by DXA, and insulin resistance was measured by Homeostatic Model Assessment-Insulin Resistance (HOMA-IR) (94). Declines in physical functioning have been associated with sarcopenic obesity, sarcopenic nonobesity, and nonsarcopenic obesity. This may be further affected by insulin resistance among different body composition phenotypes (95). Sarcopenia and metabolic syndrome coexistence increases the risks of cardiovascular diseases, type 2 diabetes mellitus, hypertension, arterial stiffness, and hyperlipidemia [parameters: DXA, HbA1c, blood pressure, body mass index, lipids, arterial Doppler stiffness, and hand-grip strength, (96)]. Low body mass and sarcopenia have been associated with depression, as evaluated by Geriatric Depression Scale (GDS) or antidepressant use (97).

Discussion

Consistent with current consensus statements, a clinical indication for DXA body composition evaluation may be considered in patients with risk factors associated with sarcopenia, such as decline in muscle (physical) functioning or strength, self-reported declines in mobility, history of recurrent falls, recent unintentional weight loss ($>5\%$), posthospitalization, malnutrition, depression, immobilization, and other specific chronic conditions associated with declining function (e.g., type II diabetes, metabolic syndrome, chronic heart failure, chronic obstructive pulmonary disease, renal disease, rheumatoid arthritis, and cancer). Clinical evaluation should include objective determination of muscle weakness (maximum grip strength or quadriceps strength) or poor physical functioning (habitual gait speed <1.0 m/s or unfavorable stand up and go test). In patients with muscle weakness or poor functioning, direct assessment of body composition using whole-body DXA should be considered for evaluation of appendicular lean mass.

Additional Questions for Future Research

Suggested sarcopenia diagnostic cutpoints were put forward by the European Working Group on Sarcopenia in Older People and by the International Working Group on Sarcopenia. These 2 definitions differ and would define the prevalence of sarcopenia at either 0.9% (European Working Group on Sarcopenia in Older People) or 2.7% (International Working Group on Sarcopenia) in the same population. Using the 2 SD appendicular lean body mass threshold for sarcopenia might conceal identification of a large number of patients who are not extremely compromised. Thus, it is necessary to initiate a global effort to identify body composition databases for different populations.

The parameters used to evaluate patients in different settings also need to be investigated. Because lean mass alone does not correlate strongly with health outcomes, perhaps, combinations of parameters, such as the residuals model (including trunk adiposity), might perform better. Different parameters or combinations of parameters may best suit different conditions. For example, the best parameter for diabetes might not be useful for HIV patients on therapy. Body shape may also define patient populations where individualization of body composition parameters can be applied.

There is increasing evidence on the association of sarcopenia and different medical conditions or diseases, but relatively few intervention trials have been conducted to examine changes in body composition in response to treatment. With the development of appropriate therapies that can target skeletal muscle mass and physical performance, there will be in need to evaluate predictive features of body composition in patients undergoing successful therapy.

What Are the Clinical Indications for DXA Body Composition in Obese Patients?

ISCD Official Position

- No position could be agreed on at this time.

Rationale

The diagnosis of obesity by body mass index and the prediction of cardiovascular risk by waist circumference measurements are simple and inexpensive techniques that are widely validated. Although DXA body composition measures excess adiposity with more accuracy and detail than anthropometry, the specific role of body composition analysis in diagnosing obesity remains unclear. In particular, there has been no consensus about the appropriate clinical thresholds to define obesity using the various parameters of adiposity (see further discussion in ''Reporting DXA Body Composition: Diagnosis of Obesity''). Therefore, it was felt to be premature to recommend the routine use of DXA body composition for the diagnosis of obesity.

Another potential application of DXA body composition may be for monitoring changes in lean and fat tissue in obese individuals undergoing large weight loss. Excessive loss of lean body mass, as determined by body composition, may motivate patients to adhere more to an exercise program during weight loss. Preservation of lean body mass may predict increased physical activity, fitness, and resistance to falling. Favorable reductions in fat mass, especially visceral adipose tissue, may predict reductions in cardiovascular risk (98). Furthermore, there are documented interventions such as dietary refinements or exercise programs that can affect these outcomes. It may be that engaging patients in diet and lifestyle interventions and motivating their adherence to an exercise or diet program will be improved with a specific physical body composition measurement.

Discussion

Frequently, in medicine, we have multiple tests that can be used to monitor a patient's physiologic change and improvement in risk profile. For example, total cholesterol measurement comprised low-density lipoprotein and high-density lipoprotein fractions. Although we could place a patient on a cholesterol-lowering medication and follow just total cholesterol, this would not capture the information required to fully determine cardiovascular risk (such as the ratio of LDL to HDL).

In a similar way, body mass index is a composite of lean and fat mass; changes in body mass index alone are insufficient to give specific information about changes in lean and fat compartments (99). This is where DXA body composition measurement may have a role to play. DXA can not only quantitate fat and lean mass but also the visceral fat (100,101), which may be useful in the evaluation of cardiometabolic risk (102). Changes in visceral adipose tissue after a weight reduction program, as measured by DXA body composition, were similar to favorable changes measured by abdominal CT scan (103). Furthermore, significant change in lean mass may be discernible after the loss of 15% of body weight in a weight reduction program.

Training programs have produced a favorable effect on lean body mass in patients on hypocaloric diets or after bariatric surgery. However, despite adherence to exercise programs, most patients lose both fat and lean body mass subsequent to bariatric surgery (63,104). Women after breast cancer randomized to a resistance exercise were demonstrated to have improvements in lean mass, and surprisingly, these improvements were greater in patients on aromatase inhibitor (105). Other studies have demonstrated beneficial effects of creatine supplementation or protein supplementation in diets to maintain lean body mass during weight reduction. In 1 study, premenopausal obese women engaging in an exercise program were randomized to high-protein high-dairy or adequate protein, low-dairy intake. The high-protein high-dairy group lost the most fat and gained the most lean mass after 16 wk (106). DXA body composition provides a method to assess the differential effects of weight loss and/or training programs on the fat and lean mass compartments for individuals.

Additional Questions for Future Research

Clearly, there is a need for more studies to prospectively validate body composition thresholds for the diagnosis of obesity and to longitudinally follow patients while undergoing different weight reduction strategies. There is also a need to develop more interventions effective at preserving muscle during weight reduction programs. Through the greater use of DXA body composition measurements in clinical practice, we will better understand on an individual basis how we can affect fat and lean mass. Eventually, specific pharmaceutical interventions to preserve muscle mass during weight reduction programs may become available. When these medications are available clinically, DXA body composition testing will likely be the test of choice to monitor the effectiveness of these therapies in patients.

What Are the Contraindications of DXA for Body Composition?

ISCD Official Position

- Pregnancy is a contraindication to DXA body composition. Limitations in the use of clinical DXA for total body composition or bone mineral density are weight over the table limit, recent administration of contrast material, and/or artifact. Radiopharmaceutical agents may interfere with accuracy of results using systems from some DXA manufacturers.
  Grade: Fair-B-W

Rationale

DXA is a low-dose X-ray test with approximately 5−30 microsieverts of radiation dose (effective) for a whole-body scan (107). The radiation dose varies according to the technology used by various manufacturers. The literature documents DXA-measured body composition use in a wide range of populations including infants, children, adolescents, adults, athletes, Caucasians, Blacks, Asians, women, and men (3,108−120). This method is used in a variety of disease states including eating disorders, HIV infection, diabetes, cancer, obesity, mobility impairment, heart, or pulmonary disease (2,18,24,121−127). No specific contraindications to perform DXA body composition have been identified in the literature. Although not specifically contraindicated, it is our position that DXA body composition should not be performed in pregnant women. As noted earlier, the effective radiation dose is extremely low and unlikely to harm a fetus. This is acknowledged by McCollough et al (128), who concluded that fetal risks from radiation doses <50 mGy are negligible, and therefore, radiologic and nuclear medicine examinations that may provide significant diagnostic information should not be withheld from pregnant women (128). However, our position is that DXA-measured body composition is unlikely to provide valuable diagnostic information during pregnancy. Consequently, there is not sufficient justification of radiation exposure, and use in pregnant women should be avoided.

Table Weight Limits

The position to avoid scanning individuals exceeding the table weight limit is justified by the manufacturers' guidelines *(129,130)*. These limits have been established for each device type based on the structural integrity and design of the instrument and, in some cases, also the ability to precisely and accurately measure patients at certain weights, likely because of inadequate penetration of the X-ray.

Contrast Agents

Contrast media and radiopharmaceuticals may be confounders for DXA assessments with most instruments *(131,132)*. They are, however, not true contraindications as once the contrast or isotope clears the body, there is no effect on DXA measurements. The length of time the artifact persists varies. Intravenous contrast agents clear more rapidly than oral. Barium and iodine studies cause considerable artifact, elevating determined densitometry readings *(131)*. The magnitude of effect on whole-body DXA by iodine contrast has been documented; increases in whole-body bone mineral content of 125%, lean mass of 110%, and fat mass of 80% 3 hr after contrast administration were observed. Measurements returned to baseline 1 wk later *(131)*.

The effect of nuclear medicine isotopes is more controversial. There may be differences between technetium (Tc-99) and gadolinium (Ga-67), and this likely varies by DXA manufacturer. There are reports of radiopharmaceutical effects on GE *(133–135)*, but not Hologic systems *(132,136)*, and no data on other manufactures. Phantom studies suggest no effect of Tc-99 using Hologic equipment, but a source location and dose-dependent effect were observed with GE instruments *(137)*, perhaps, attributable to the differences in detector systems.

Discussion

These positions are intended to guide the use of DXA for total body composition in relationship to risk (pregnancy), safety for scanner equipment (table weight), and accuracy (weight, isotope, and contrast media). Because there is the possibility of artifact from recent isotope or contrast studies, a delay in DXA body composition studies sufficient to clear the agent from the body is prudent. The time allowed for artifact to clear should be based on the specific isotope or contrast agent.

Additional Questions for Future Research

There are limited data on the impact of contrast media and radiopharmaceuticals on DXA-measured body composition, especially with instruments not manufactured by Hologic or GE. Further studies evaluating how these agents affect body composition measurements on various DXA systems and the time course of elimination are warranted.

Acknowledgments

The contribution by RAF is partially supported by the US Department of Agriculture under agreement no. 58-1950-0-014. Any opinions, findings, conclusion, or recommendations expressed in this publication are those of the authors and do not necessarily reflect the view of the US Department of Agriculture.

We appreciate the comments received from representatives of instrument manufacturers including Kevin Wilson, Tom Sanchez, and David Ergun.

References

1. Olbers T, Bjorkman S, Lindroos A, et al. 2006 Body composition, dietary intake, and energy expenditure after laparoscopic Roux-en-Y gastric bypass and laparoscopic vertical banded gastroplasty: a randomized clinical trial. Ann Surg 244(5): 715–722.
2. Bredella MA, Ghomi RH, Thomas BJ, et al. 2010 Comparison of DXA and CT in the assessment of body composition in premenopausal women with obesity and anorexia nervosa. Obesity (Silver Spring) 18(11):2227–2233.
3. Bridge P, Pocock NA, Nguyen T, et al. 2011 Validation of longitudinal DXA changes in body composition from pre- to mid-adolescence using MRI as reference. J Clin Densitom 14(3): 340–347.
4. Scherzer R, Shen W, Bacchetti P, et al. 2008 Comparison of dual-energy X-ray absorptiometry and magnetic resonance imaging-measured adipose tissue depots in HIV-infected and control subjects. Am J Clin Nutr 88(4):1088–1096.
5. Fakhrawi DH, Beeson L, Libanati C, et al. 2009 Comparison of body composition by bioelectrical impedance and dual-energy x-ray absorptiometry in overweight/obese postmenopausal women. J Clin Densitom 12(2):238–244.
6. Xu L, Cheng X, Wang J, et al. 2011 Comparisons of body-composition prediction accuracy: a study of 2 bioelectric impedance consumer devices in healthy Chinese persons using DXA and MRI as criteria methods. J Clin Densitom 14(4): 458–464.
7. Lustgarten MS, Fielding RA. 2011 Assessment of analytical methods used to measure changes in body composition in the elderly and recommendations for their use in phase II clinical trials. J Nutr Health Aging 15(5):368–375.
8. Di Sebastiano KM, Mourtzakis M. 2012 A critical evaluation of body composition modalities used to assess adipose and skeletal muscle tissue in cancer. Appl Physiol Nutr Metab 37(5):811–821.
9. Woodrow G. 2009 Body composition analysis techniques in the aged adult: indications and limitations. Curr Opin Clin Nutr Metab Care 12(1):8–14.
10. Park YW, Heymsfield SB, Gallagher D. 2002 Are dual-energy X-ray absorptiometry regional estimates associated with visceral adipose tissue mass? Int J Obes Relat Metab Disord 26(7):978–983.
11. Kaul S, Rothney MP, Peters DM, et al. 2012 Dual-energy X-ray absorptiometry for quantification of visceral fat. [Erratum appears in Obesity (Silver Spring). 2012;20(7):1544]. Obesity (Silver Spring) 20(6):1313–1318.
12. Micklesfield LK, Goedecke JH, Punyanitya M, et al. 2012 Dual-energy X-ray performs as well as clinical computed tomography for the measurement of visceral fat. Obesity (Silver Spring) 20(5):1109–1114.
13. Mattsson S, Thomas BJ. 2006 Development of methods for body composition studies. Phys Med Biol 51(13):R203–R228.
14. Matthie J, Zarowitz B, De Lorenzo A, et al. 1998 Analytic assessment of the various bioimpedance methods used to estimate body water. J Appl Physiol 84(5):1801–1816.

15. Yamada Y, Schoeller DA, Nakamura E, et al. 2010 Extracellular water may mask actual muscle atrophy during aging. J Gerontol A Biol Sci Med Sci 65(5):510−516.
16. Wagner DR, Heyward VH. 1999 Techniques of body composition assessment: a review of laboratory and field methods. Res Q Exerc Sport 70(2):135−149.
17. Ackland TR, Lohman TG, Sundgot-Borgen J, et al. 2012 Current status of body composition assessment in sport: review and position statement on behalf of the ad hoc research working group on body composition health and performance, under the auspices of the I.O.C. Medical Commission. Sports Med 42(3):227−249.
18. Vrouenraets SM, Wit FW, Garcia EF, et al. 2012 Longer prior exposure to zidovudine/lamivudine-containing combination antiretroviral therapy, age, and male gender are each associated with reduced subcutaneous adipose tissue. HIV Clin Trials 13(2):103−110.
19. Dube MP, Komarow L, Mulligan K, et al. 2007 Long-term body fat outcomes in antiretroviral-naive participants randomized to nelfinavir or efavirenz or both plus dual nucleosides. Dual X-ray absorptiometry results from A5005s, a substudy of Adult Clinical Trials Group 384. J Acquir Immune Defic Syndr 45(5):508−514.
20. Yang Y, Wilder-Smith A, Panchalingam A, et al. 2005 Changes in body fat measured by DEXA in patients taking different formulations of stavudine. HIV Clin Trials 6(6):337−343.
21. Dube MP, Parker RA, Tebas P, et al. 2005 Glucose metabolism, lipid, and body fat changes in antiretroviral-naive subjects randomized to nelfinavir or efavirenz plus dual nucleosides. AIDS 19(16):1807−1818.
22. McComsey GA, Kitch D, Sax PE, et al. 2011 Peripheral and central fat changes in subjects randomized to abacavir-lamivudine or tenofovir-emtricitabine with atazanavir-ritonavir or efavirenz: ACTG Study A5224s. Clin Infect Dis 53(2):185−196.
23. Mulligan K, Parker RA, Komarow L, et al. 2006 Mixed patterns of changes in central and peripheral fat following initiation of antiretroviral therapy in a randomized trial. J Acquir Immune Defic Syndr 41(5):590−597.
24. Moyle GJ, Andrade-Villanueva J, Girard PM, et al. 2012 A randomized comparative 96-week trial of boosted atazanavir versus continued boosted protease inhibitor in HIV-1 patients with abdominal adiposity. Antivir Ther 17(4):689−700.
25. Curran A, Martinez E, Podzamczer D, et al. 2012 Changes in body composition and mitochondrial DNA in HIV-1-infected patients switching to fixed-dose abacavir/lamivudine or tenofovir/emtricitabine: a substudy of the BICOMBO trial. Antivir Ther 17(4):711−718.
26. Negredo E, Miro O, Rodriguez-Santiago B, et al. 2009 Improvement of mitochondrial toxicity in patients receiving a nucleoside reverse-transcriptase inhibitor-sparing strategy: results from the Multicenter Study with Nevirapine and Kaletra (MULTINEKA). Clin Infect Dis 49(6):892−900.
27. Ananworanich J, Nuesch R, Cote HCF, et al. 2008 Changes in metabolic toxicity after switching from stavudine/didanosine to tenofovir/lamivudine−a Staccato trial substudy. J Antimicrob Chemother 61(6):1340−1343.
28. Martin A, Smith D, Carr A, et al. 2004 Progression of lipodystrophy (LD) with continued thymidine analogue usage: long-term follow-up from a randomized clinical trial (the PIILR study). HIV Clin Trials 5(4):192−200.
29. Moyle GJ, Baldwin C, Langroudi B, et al. 2003 A 48-week, randomized, open-label comparison of three abacavir-based substitution approaches in the management of dyslipidemia and peripheral lipoatrophy. J Acquir Immune Defic Syndr 33(1):22−28.
30. Carr A, Workman C, Smith DE, et al. 2002 Abacavir substitution for nucleoside analogs in patients with HIV lipoatrophy: a randomized trial. JAMA 288(2):207−215.
31. Martinez E, Visnegarwala F, Grund B, et al. 2010 The effects of intermittent, CD4-guided antiretroviral therapy on body composition and metabolic parameters. AIDS 24(3):353−363.
32. Cooper DA, Cordery DV, Reiss P, et al. 2011 The effects of enfuvirtide therapy on body composition and metabolic parameters over 48 weeks in the TORO body imaging substudy. HIV Med 12(1):31−39.
33. Hammond E, McKinnon E, Nolan D. 2010 Human immunodeficiency virus treatment-induced adipose tissue pathology and lipoatrophy: prevalence and metabolic consequences. Clin Infect Dis 51(5):591−599.
34. Guaraldi G, Orlando G, Squillace N, et al. 2006 Multidisciplinary approach to the treatment of metabolic and morphologic alterations of HIV-related lipodystrophy. HIV Clin Trials 7(3): 97−106.
35. Falutz J, Allas S, Blot K, et al. 2007 Metabolic effects of a growth hormone-releasing factor in patients with HIV. N Engl J Med 357(23):2359−2370.
36. Falutz J, Potvin D, Mamputu J-C, et al. 2010 Effects of tesamorelin, a growth hormone-releasing factor, in HIV-infected patients with abdominal fat accumulation: a randomized placebo-controlled trial with a safety extension. J Acquir Immune Defic Syndr 53(3):311−322.
37. Grunfeld C, Thompson M, Brown SJ, et al. 2007 Recombinant human growth hormone to treat HIV-associated adipose redistribution syndrome: 12 week induction and 24-week maintenance therapy. J Acquir Immune Defic Syndr 45(3):286−297.
38. Kotler DP, Muurahainen N, Grunfeld C, et al. 2004 Effects of growth hormone on abnormal visceral adipose tissue accumulation and dyslipidemia in HIV-infected patients. [Erratum appears in J Acquir Immune Defic Syndr. 2006;43(3):381], [Erratum for J Acquir Immune Defic Syndr. 2006;43(3): 378−80; PMID: 17079997]. J Acquir Immune Defic Syndr 35(3):239−252.
39. Macallan DC, Baldwin C, Mandalia S, et al. 2008 Treatment of altered body composition in HIV-associated lipodystrophy: comparison of rosiglitazone, pravastatin, and recombinant human growth hormone. HIV Clin Trials 9(4):254−268.
40. Hadigan C, Yawetz S, Thomas A, et al. 2004 Metabolic effects of rosiglitazone in HIV lipodystrophy: a randomized, controlled trial. Ann Intern Med 140(10):786−794.
41. Carr A, Workman C, Carey D, et al. 2004 No effect of rosiglitazone for treatment of HIV-1 lipoatrophy: randomised, double-blind, placebo-controlled trial. Lancet 363(9407):429−438.
42. Mulligan K, Yang Y, Wininger DA, et al. 2007 Effects of metformin and rosiglitazone in HIV-infected patients with hyperinsulinemia and elevated waist/hip ratio. AIDS 21(1):47−57.
43. Slama L, Lanoy E, Valantin M-A, et al. 2008 Effect of pioglitazone on HIV-1-related lipodystrophy: a randomized double-blind placebo-controlled trial (ANRS 113). Antivir Ther 13(1):67−76.
44. Cavalcanti RB, Raboud J, Shen S, et al. 2007 A randomized, placebo-controlled trial of rosiglitazone for HIV-related lipoatrophy. J Infect Dis 195(12):1754−1761.
45. Kohli R, Shevitz A, Gorbach S, Wanke C. 2007 A randomized placebo-controlled trial of metformin for the treatment of HIV lipodystrophy. HIV Med 8(7):420−426.
46. Calmy A, Bloch M, Wand H, et al. 2010 No significant effect of uridine or pravastatin treatment for HIV lipoatrophy in men who have ceased thymidine analogue nucleoside reverse transcriptase inhibitor therapy: a randomized trial. HIV Med 11(8):493−501.

47. Bhasin S, Parker RA, Sattler F, et al. 2007 Effects of testosterone supplementation on whole body and regional fat mass and distribution in human immunodeficiency virus-infected men with abdominal obesity. J Clin Endocrinol Metab 92(3): 1049−1057.
48. Smith DE, Hudson J, Martin A, et al. 2003 Centralized assessment of dual-energy X-ray absorptiometry (DEXA) in multicenter studies of HIV-associated lipodystrophy. HIV Clin Trials 4(1):45−49.
49. Cavalcanti RB, Cheung AM, Raboud J, Walmsley S. 2005 Reproducibility of DXA estimations of body fat in HIV lipodystrophy: implications for clinical research. J Clin Densitom 8(3): 293−297.
50. Carr A, Samaras K, Burton S, et al. 1998 A syndrome of peripheral lipodystrophy, hyperlipidaemia and insulin resistance in patients receiving HIV protease inhibitors. AIDS 12(7): F51−F58.
51. Lo JC, Mulligan K, Tai VW, et al. 1998 "Buffalo hump" in men with HIV-1 infection. Lancet 351(9106):867−870.
52. Mulligan K, Tai VW, Algren H, et al. 2001 Altered fat distribution in HIV-positive men on nucleoside analog reverse transcriptase inhibitor therapy. J Acquir Immune Defic Syndr 26(5):443−448.
53. Vigano A, Mora S, Testolin C, et al. 2003 Increased lipodystrophy is associated with increased exposure to highly active antiretroviral therapy in HIV-infected children. J Acquir Immune Defic Syndr 32(5):482−489.
54. Brambilla P, Bricalli D, Sala N, et al. 2001 Highly active antiretroviral-treated HIV-infected children show fat distribution changes even in absence of lipodystrophy. AIDS 15(18): 2415−2422.
55. Melvin AJ, Lennon S, Mohan KM, Purnell JQ. 2001 Metabolic abnormalities in HIV type 1-infected children treated and not treated with protease inhibitors. AIDS Res Hum Retroviruses 17(12):1117−1123.
56. Carr A, Emery S, Law M, et al. 2003 An objective case definition of lipodystrophy in HIV-infected adults: a case-control study. Lancet 361(9359):726−735.
57. Chaston TB, Dixon JB, O'Brien PE. 2007 Changes in fat-free mass during significant weight loss: a systematic review. Int J Obes (Lond) 31(5):743−750.
58. Bales CW, Buhr G. 2008 Is obesity bad for older persons? A systematic review of the pros and cons of weight reduction in later life. J Am Med Dir Assoc 9(5):302−312.
59. Waters DL, Ward AL, Villareal DT. 2013 Weight loss in obese adults 65 years and older: a review of the controversy. Exp Gerontol 48(10):1054−1061.
60. Dixon JB, Strauss BJG, Laurie C, O'Brien PE. 2007 Changes in body composition with weight loss: obese subjects randomized to surgical and medical programs. Obesity (Silver Spring) 15(5):1187−1198.
61. Vatier C, Henegar C, Ciangura C, et al. 2012 Dynamic relations between sedentary behavior, physical activity, and body composition after bariatric surgery. Obes Surg 22(8): 1251−1256.
62. Clements RH, Saraf N, Kakade M, et al. 2011 Nutritional effect of oral supplement enriched in beta-hydroxy-beta-methylbutyrate, glutamine and arginine on resting metabolic rate after laparoscopic gastric bypass. Surg Endosc 25(5): 1376−1382.
63. Ciangura C, Bouillot J-L, Lloret-Linares C, et al. 2010 Dynamics of change in total and regional body composition after gastric bypass in obese patients. Obesity (Silver Spring) 18(4): 760−765.
64. Andreu A, Moize V, Rodriguez L, et al. 2012 Protein intake, body composition, and protein status following bariatric surgery. Obes Surg 20(11):1509−1515.
65. Tamboli RA, Hossain HA, Marks PA, et al. 2010 Body composition and energy metabolism following Roux-en-Y gastric bypass surgery. Obesity (Silver Spring) 18(9):1718−1724.
66. Carrasco F, Ruz M, Rojas P, et al. 2009 Changes in bone mineral density, body composition and adiponectin levels in morbidly obese patients after bariatric surgery. Obes Surg 19(1): 41−46.
67. Levitt DG, Beckman LM, Mager JR, et al. 2010 Comparison of DXA and water measurements of body fat following gastric bypass surgery and a physiological model of body water, fat, and muscle composition. J Appl Physiol 109(3):786−795.
68. Giusti V, Suter M, Heraief E, et al. 2004 Effects of laparoscopic gastric banding on body composition, metabolic profile and nutritional status of obese women: 12-months follow-up. Obes Surg 14(2):239−245.
69. Coupaye M, Bouillot J-L, Coussieu C, et al. 2005 One-year changes in energy expenditure and serum leptin following adjustable gastric banding in obese women. Obes Surg 15(6): 827−833.
70. Coupaye M, Bouillot J-L, Poitou C, et al. 2007 Is lean body mass decreased after obesity treatment by adjustable gastric banding? Obes Surg 17(4):427−433.
71. Inge T, Wilson KA, Gamm K, et al. 2007 Preferential loss of central (trunk) adiposity in adolescents and young adults after laparoscopic gastric bypass. Surg Obes Relat Dis 3(2):153−158.
72. Strauss BJG, Marks SJ, Growcott JP, et al. 2003 Body composition changes following laparoscopic gastric banding for morbid obesity. Acta Diabetol 40(1 Suppl):S266−S269.
73. Sergi G, Lupoli L, Busetto L, et al. 2003 Changes in fluid compartments and body composition in obese women after weight loss induced by gastric banding. Ann Nutr Metab 47(3−4): 152−157.
74. Villareal DT, Chode S, Parimi N, et al. 2011 Weight loss, exercise, or both and physical function in obese older adults. N Engl J Med 364(13):1218−1229.
75. Frimel TN, Sinacore DR, Villareal DT. 2008 Exercise attenuates the weight-loss-induced reduction in muscle mass in frail obese older adults. Med Sci Sports Exerc 40(7):1213−1219.
76. Shah K, Stufflebam A, Hilton TN, et al. 2009 Diet and exercise interventions reduce intrahepatic fat content and improve insulin sensitivity in obese older adults. Obesity (Silver Spring) 17(12):2162−2168.
77. Janssen I, Ross R. 1999 Effects of sex on the change in visceral, subcutaneous adipose tissue and skeletal muscle in response to weight loss. Int J Obes Relat Metab Disord 23(10): 1035−1046.
78. Rice B, Janssen I, Hudson R, Ross R. 1999 Effects of aerobic or resistance exercise and/or diet on glucose tolerance and plasma insulin levels in obese men. Diabetes Care 22(5):684−691.
79. Janssen I, Fortier A, Hudson R, Ross R. 2002 Effects of an energy-restrictive diet with or without exercise on abdominal fat, intermuscular fat, and metabolic risk factors in obese women. Diabetes Care 25(3):431−438.
80. Coates PS, Fernstrom JD, Fernstrom MH, et al. 2004 Gastric bypass surgery for morbid obesity leads to an increase in bone turnover and a decrease in bone mass. J Clin Endocrinol Metab 89(3):1061−1065.
81. Johnson JM, Maher JW, Samuel I, et al. 2005 Effects of gastric bypass procedures on bone mineral density, calcium, parathyroid hormone, and vitamin D. J Gastrointest Surg 9(8): 1106−1110. discussion 1110−1.

82. Fleischer J, Stein EM, Bessler M, et al. 2008 The decline in hip bone density after gastric bypass surgery is associated with extent of weight loss. J Clin Endocrinol Metab 93(10):3735−3740.
83. Anonymous. 2003 Prevention and management of osteoporosis. World Health Organ Tech Rep Ser 921:1−164. [back cover].
84. Knapp KM, Welsman JR, Hopkins SJ, et al. 2012 Obesity increases precision errors in dual-energy X-ray absorptiometry measurements. J Clin Densitom 15(3):315−319.
85. Yu EW, Thomas BJ, Brown JK, Finkelstein JS. 2012 Simulated increases in body fat and errors in bone mineral density measurements by DXA and QCT. J Bone Miner Res 27(1): 119−124.
86. Tothill P, Hannan WJ, Wilkinson S. 2001 Comparisons between a pencil beam and two fan beam dual energy X-ray absorptiometers used for measuring total body bone and soft tissue. Br J Radiol 74(878):166−176.
87. Glickman SG, Marn CS, Supiano MA, Dengel DR. 2004 Validity and reliability of dual-energy X-ray absorptiometry for the assessment of abdominal adiposity. J Appl Physiol 97(2): 509−514.
88. Kim S-H, Kim T-H, Hwang H-J. 2013 The relationship of physical activity (PA) and walking with sarcopenia in Korean males aged 60 years and older using the Fourth Korean National Health and Nutrition Examination Survey (KNHANES IV-2, 3), 2008-2009. Arch Gerontol Geriatr 56(3):472−477.
89. Bouchard DR, Dionne IJ, Brochu M. 2009 Sarcopenic/obesity and physical capacity in older men and women: data from the Nutrition as a Determinant of Successful Aging (NuAge)-the Quebec longitudinal Study. Obesity (Silver Spring) 17(11): 2082−2088.
90. Dufour AB, Hannan MT, Murabito JM, et al. 2013 Sarcopenia definitions considering body size and fat mass are associated with mobility limitations: the Framingham Study. J Gerontol A Biol Sci Med Sci 68(2):168−174.
91. Patil R, Uusi-Rasi K, Pasanen M, et al. 2013 Sarcopenia and osteopenia among 70-80-year-old home-dwelling Finnish women: prevalence and association with functional performance. Osteoporos Int 24(3):787−796.
92. Koster A, Ding J, Stenholm S, et al. 2011 Does the amount of fat mass predict age-related loss of lean mass, muscle strength, and muscle quality in older adults? J Gerontol A Biol Sci Med Sci 66(8):888−895.
93. Auyeung TW, Lee JSW, Leung J, et al. 2012 Adiposity to muscle ratio predicts incident physical limitation in a cohort of 3,153 older adults-an alternative measurement of sarcopenia and sarcopenic obesity. Age 35(4):1377−1385.
94. Lee CG, Boyko EJ, Strotmeyer ES, et al. 2011 Association between insulin resistance and lean mass loss and fat mass gain in older men without diabetes mellitus. J Am Geriatr Soc 59(7): 1217−1224.
95. Levine ME, Crimmins EM. 2012 The impact of insulin resistance and inflammation on the association between sarcopenic obesity and physical functioning. Obesity (Silver Spring) 20(10):2101−2106.
96. Sanada K, Iemitsu M, Murakami H, et al. 2012 Adverse effects of coexistence of sarcopenia and metabolic syndrome in Japanese women. Eur J Clin Nutr 66(10):1093−1098.
97. Kim NH, Kim HS, Eun CR, et al. 2011 Depression is associated with sarcopenia, not central obesity, in elderly Korean men. J Am Geriatr Soc 59(11):2062−2068.
98. Borel A-L, Nazare J-A, Smith J, et al. 2012 Visceral and not subcutaneous abdominal adiposity reduction drives the benefits of a 1-year lifestyle modification program. Obesity (Silver Spring) 20(6):1223−1233.
99. Shah NR, Braverman ER. 2012 Measuring adiposity in patients: the utility of body mass index (BMI), percent body fat, and leptin. PLoS One 7(4):e33308. [Electronic Resource].
100. Rothney MP, Catapano AL, Xia J, et al. 2012 Abdominal visceral fat measurement using dual-energy X-ray: association with cardiometabolic risk factors. Obesity (Silver Spring). Dec 12. [Epub ahead of print].
101. Rothney MP, Xia Y, Wacker WK, et al. 2013 Precision of a new tool to measure visceral adipose tissue (VAT) using dual-energy X-Ray absorptiometry (DXA). Obesity (Silver Spring) 21(1): E134−E136.
102. Ergun DL, Rothney MP, Oates MK, et al. 2013 Visceral adipose tissue quantification using lunar prodigy. J Clin Densitom 16(1):75−78.
103. Karelis AD, Rabasa-Lhoret R, Pompilus R, et al. 2012 Relationship between the Bertin index to estimate visceral adipose tissue from dual-energy X-ray absorptiometry and cardiometabolic risk factors before and after weight loss. Obesity (Silver Spring) 20(4):886−890.
104. Zalesin KC, Franklin BA, Lillystone MA, et al. 2010 Differential loss of fat and lean mass in the morbidly obese after bariatric surgery. Metab Syndr Relat Disord 8(1):15−20.
105. Winters-Stone KM, Dobek J, Nail LM, et al. 2012 Impact + resistance training improves bone health and body composition in prematurely menopausal breast cancer survivors: a randomized controlled trial. Osteoporos Int 24(5):1637−1646.
106. Josse AR, Atkinson SA, Tarnopolsky MA, Phillips SM. 2011 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(9):1626−1634.
107. Hull H, He Q, Thornton J, et al. 2009 iDXA, prodigy, and DPXL dual-energy X-ray absorptiometry whole-body scans: a cross-calibration study. J Clin Densitom 12(1):95−102.
108. Ioannou C, Javaid MK, Mahon P, et al. 2012 The effect of maternal vitamin D concentration on fetal bone. J Clin Endocrinol Metab 97(11):E2070−E2077.
109. Azocar MA, Cano FJ, Marin V, et al. 2004 Body composition in children on peritoneal dialysis. Adv Perit Dial 20:231−236.
110. Fields DA, Demerath EW. 2012 Relationship of insulin, glucose, leptin, IL-6 and TNF in human breast milk with infant growth and body composition. Pediatr Obes 7(4):304−312.
111. Crozier SR, Harvey NC, Inskip HM, et al. 2012 Maternal vitamin D status in pregnancy is associated with adiposity in the offspring: findings from the Southampton Women's Survey. Am J Clin Nutr 96(1):57−63.
112. Bacha F, Gungor N, Lee S, Arslanian SA. 2012 Type 2 diabetes in youth: are there racial differences in cell responsiveness relative to insulin sensitivity? Pediatr Diabetes 13(3):259−265.
113. Libber J, Binkley N, Krueger D. 2012 Clinical observations in total body DXA: technical aspects of positioning and analysis. J Clin Densitom 15(3):282−289.
114. Ryder KM, Shorr RI, Tylavsky FA, et al. 2006 Correlates of use of antifracture therapy in older women with low bone mineral density. J Gen Intern Med 21(6):636−641.
115. Nielsen TL, Hagen C, Wraae K, et al. 2010 The impact of the CAG repeat polymorphism of the androgen receptor gene on muscle and adipose tissues in 20-29-year-old Danish men: Odense Androgen Study. Eur J Endocrinol 162(4):795−804.
116. Clark RR, Bartok C, Sullivan JC, Schoeller DA. 2005 Is leg-to-leg BIA valid for predicting minimum weight in wrestlers? Med Sci Sports Exerc 37(6):1061−1068.
117. Gallagher D, Heymsfield SB, Heo M, et al. 2000 Healthy percentage body fat ranges: an approach for developing guidelines based on body mass index. Am J Clin Nutr 72(3):694−701.

118. Vikram NK, Bhatt SP, Bhushan B, et al. 2011 Associations of -308G/A polymorphism of tumor necrosis factor (TNF)-gene and serum TNF levels with measures of obesity, intra-abdominal and subcutaneous abdominal fat, subclinical inflammation and insulin resistance in Asian Indians in north India. Dis Markers 31(1):39−46.
119. Van Pelt RE, Jankowski CM, Gozansky WS, et al. 2011 Sex differences in the association of thigh fat and metabolic risk in older adults. Obesity (Silver Spring) 19(2):422−428.
120. El-Maouche D, Xu X, Cofrancesco J Jr, et al. 2011 Prevalence of low bone mineral density in a low-income inner-city population. J Bone Miner Res 26(2):388−396.
121. Jebb SA, Osborne RJ, Dixon AK, et al. 1994 Measurements of resting energy expenditure and body composition before and after treatment of small cell lung cancer. Ann Oncol 5(10): 915−919.
122. Mourtzakis M, Prado CM, Lieffers JR, et al. 2008 A practical and precise approach to quantification of body composition in cancer patients using computed tomography images acquired during routine care. Appl Physiol Nutr Metab 33(5):997−1006.
123. Johnson RK, Hildreth HG, Contompasis SH, Goran MI. 1997 Total energy expenditure in adults with cerebral palsy as assessed by doubly labeled water. J Am Diet Assoc 97(9): 966−970.
124. Sode-Carlsen R, Farholt S, Rabben KF, et al. 2011 Growth hormone treatment for two years is safe and effective in adults with Prader-Willi syndrome. Growth Horm IGF Res 21(4): 185−190.
125. Fontana L, Villareal DT, Weiss EP, et al. 2007 Calorie restriction or exercise: effects on coronary heart disease risk factors. A randomized, controlled trial. Am J Physiol Endocrinol Metab 293(1):E197−E202.
126. Aubertin-Leheudre M, Lord C, Goulet ED, et al. 2006 Effect of sarcopenia on cardiovascular disease risk factors in obese postmenopausal women. Obesity (Silver Spring) 14(12):2277−2283.
127. Engelen MP, Schols AM, Heidendal GA, Wouters EF. 1998 Dual-energy X-ray absorptiometry in the clinical evaluation of body composition and bone mineral density in patients with chronic obstructive pulmonary disease. Am J Clin Nutr 68(6):1298−1303.
128. McCollough CH, Schueler BA, Atwell TD, et al. 2007 Radiation exposure and pregnancy: when should we be concerned? Radiographics 27(4):909−917. discussion 917−8.
129. Hologic. 2013 Discovery Series FAQs. Accessed February 20, 2013, http://www.hologic.com/data/ProductSupport/Densitometry/Discovery/FAQs/Discovery-FAQ.pdf.
130. GEHealthcare. 2013 GEHealthcare-iDXA-Advance-Package-ProductSpec. Accessed February 20, 2013, http://www3.gehealthcare.com/en/Products/Categories/Metabolic_Health/DXA_for_Metabolic_Health/~/media/Downloads/us/Product/Product-Categories/Metabolic-Health/Lunar-iDXA-for-Metabolic-Health/GEHealthcare-iDXA-Advance-Package-ProductSpec.pdf.
131. Jacobson JA, Jamadar DA, Hayes CW. 2000 Dual X-ray absorptiometry: recognizing image artifacts and pathology. AJR Am J Roentgenol 174(6):1699−1705.
132. Sala A, Webber C, Halton J, et al. 2006 Effect of diagnostic radioisotopes and radiographic contrast media on measurements of lumbar spine bone mineral density and body composition by dual-energy x-ray absorptiometry. J Clin Densitom 9(1):91−96.
133. Chan PS, Binkley NC, Lalande BM, et al. 2004 Artifactual reduction in bone density as a result of technetium-99m MDP for bone scanning: report of two cases. J Clin Densitom 7(4): 457−458.
134. McKiernan FE, Hocking J, Cournoyer S. 2006 Antecedent 99mTc-MDP and 99mTc-sestamibi administration corrupts bone mineral density measured by DXA. J Clin Densitom 9(2):164−166.
135. Gumuser G, Parlak Y, Topal G, et al. 2009 Effects of 99mTc-MIBI and 99mTc-MDP administration on dual-energy X-ray absorptiometry bone mineral density measurements. Nucl Med Commun 30(6):445−448.
136. Campbell A, McCarthy M, Blake M, Roff G. 2005 Effect of 99mTc-MDP administration on dual-energy X-ray absorptiometry bone mineral density measurements. J Clin Densitom 8(1):14−17.
137. Mueller B, O'Connor MK. 2002 Effects of radioisotopes on the accuracy of dual-energy X-ray absorptiometry for bone densitometry. J Clin Densitom 5(3):283−287.

Appendix

Search Criteria to Answer Indications Task Force Questions

Name of Search: Body composition monitoring
Search: (((((((DXA OR DEXA)) AND (((((body composition)) OR percent body fat) OR percent fat) OR lean body mass))) AND (''1986/1/1''[Date - Create] : ''3000''[Date - Create]))) AND ''english''[Language]) AND ''humans'' [Filter] AND (''serial'' OR ''monitoring'')
Name of Search: anorexia/cachexia
Search: (((((((DXA OR DEXA)) AND (((((body composition)) OR percent body fat) OR percent fat) OR lean body mass))) AND (''1986/1/1''[Date - Create] : ''3000''[Date - Create]))) AND ''english''[Language]) AND ''humans''[Filter] AND (''anorexia'' OR ''cachexia'' OR ''starvation'')
Name of Search: body composition by CT or MRI
Search: (((((((DXA OR DEXA)) AND (((((body composition)) OR percent body fat) OR percent fat) OR lean body mass))) AND (''1986/1/1''[Date - Create] : ''3000''[Date - Create]))) AND ''english''[Language]) AND ''humans'' [Filter] AND (''CT'' OR ''MRI'')
Name of Search: body composition indications are guidelines
Search: (((((((DXA OR DEXA)) AND (((((body composition)) OR percent body fat) OR percent fat) OR lean body mass))) AND (''1986/1/1''[Date - Create] : ''3000''[Date - Create]))) AND ''english''[Language]) AND ''humans'' [Filter] AND (''indications'' OR ''guidelines'')
Name of Search: body composition and bariatric surgery or obesity
Search: (((((((DXA OR DEXA)) AND (((((body composition)) OR percent body fat) OR percent fat) OR lean body mass))) AND (''1986/1/1''[Date - Create] : ''3000''[Date - Create]))) AND ''english''[Language]) AND ''humans'' [Filter] AND (''bariatric'' OR ''obesity'')
Name of Search: body composition and HIV/ lipodystrophy

Search: (((((((DXA OR DEXA)) AND (((((body composition)) OR percent body fat) OR percent fat) OR lean body mass))) AND (''1986/1/1''[Date - Create] : ''3000''[Date - Create]))) AND ''english''[Language]) AND ''humans''[Filter] AND (''HIV'' OR ''lipodystrophy'')

Name of Search: body composition and sarcopenia/falls
Search: (((((((DXA OR DEXA)) AND (((((body composition)) OR percent body fat) OR percent fat) OR lean body mass))) AND (''1986/1/1''[Date - Create] : ''3000''[Date - Create]))) AND ''english''[Language]) AND ''humans''[Filter] AND (''sarcopenia'' OR ''fall'')