Body composition: impact on disease risk and how to assess and improve it

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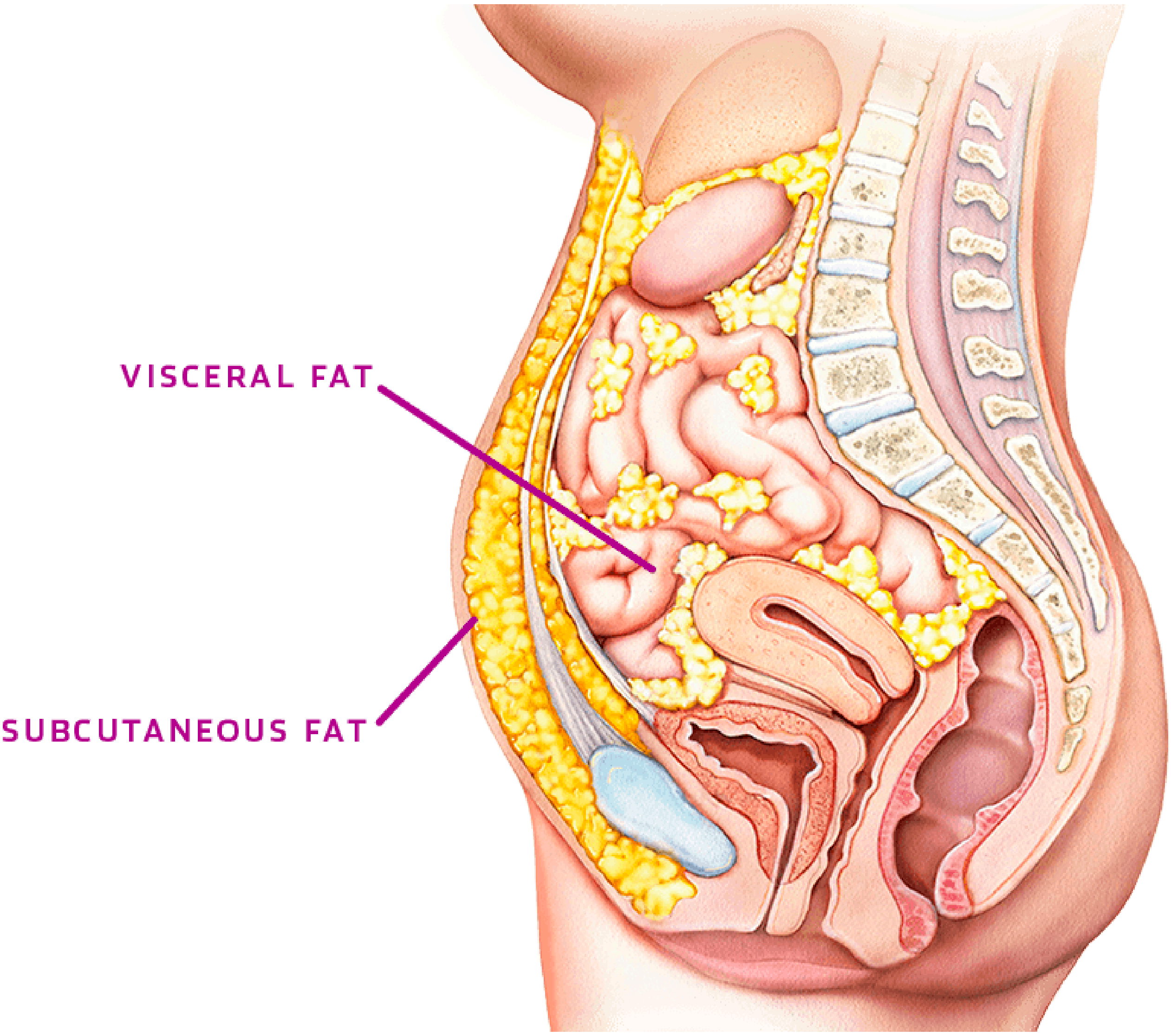

Countless different metrics are used to assess metabolic health. Body mass index (BMI) – the mass of the body divided by height squared – is among the simplest and most commonly used, but while BMI may provide a fair indication of overall trends in metabolic health across a given *population*, it falls short for assessing the metabolic health of any given *individual.* I often joke that at the individual level, it tells me little more about one of my patients' health than their eye color! The reason for this failure is that BMI does not take into account how mass is distributed between fat mass and lean mass, which have largely opposing effects on metabolic health. In other words, BMI provides no information about *body composition*, a set of variables with far more relevance to health and mortality than body weight or BMI alone.

The importance of body composition for healthspan and lifespan cannot be overstated, which is why it is a subject that repeatedly comes up in our content (e.g., see AMA 17, AMA 40, and AMA 44). So given its importance, how do we know where we stand with respect to body composition? What are the best ways of assessing body composition, and what are their respective limitations? Which metrics in particular are most predictive of healthspan and lifespan, and what are the ideal values we should be aiming for within each? We will devote the rest of this piece to exploring these key questions in depth.

Body composition: biology and significance

Broadly speaking, we are concerned with two elements with regard to body composition: fat mass and lean mass. Before we begin any discussion of body composition measurement, it is essential that we understand key nuances of each of these elements and their effects on health.

Fat Mass

Adipose tissue,[1] commonly referred to as “fat mass,” is linked[2] to higher risk of all-cause mortality (ACM) when present in large amounts throughout the body. For instance, mendelian randomization (MR) studies, which leverage genetic variants (assumed to be randomly distributed throughout the population) to mimic a randomized controlled trial using observational data, have shown that high genetically predicted fat mass is associated[3] with a higher risk of ACM.

However, not all fat mass is created equal. Fat exists in two main forms based on its location within the body: subcutaneous adipose tissue and non-subcutaneous adipose tissue (**Figure 1**). Subcutaneous fat consists of the fat that is found underneath the skin, most commonly around the hips, thighs, belly, and butt, and it represents the “normal” form of fat storage. Non-subcutaneous fat can be found around the viscera (or soft internal organs, where it is referred to as visceral fat or VAT), and incorporated into the pancreas, liver, and within muscle. Non-subcutaneous fat typically accumulates as the body’s capacity for subcutaneous fat storage reaches its limit, and it is this form of fat that creates the most problems with respect to metabolic health.

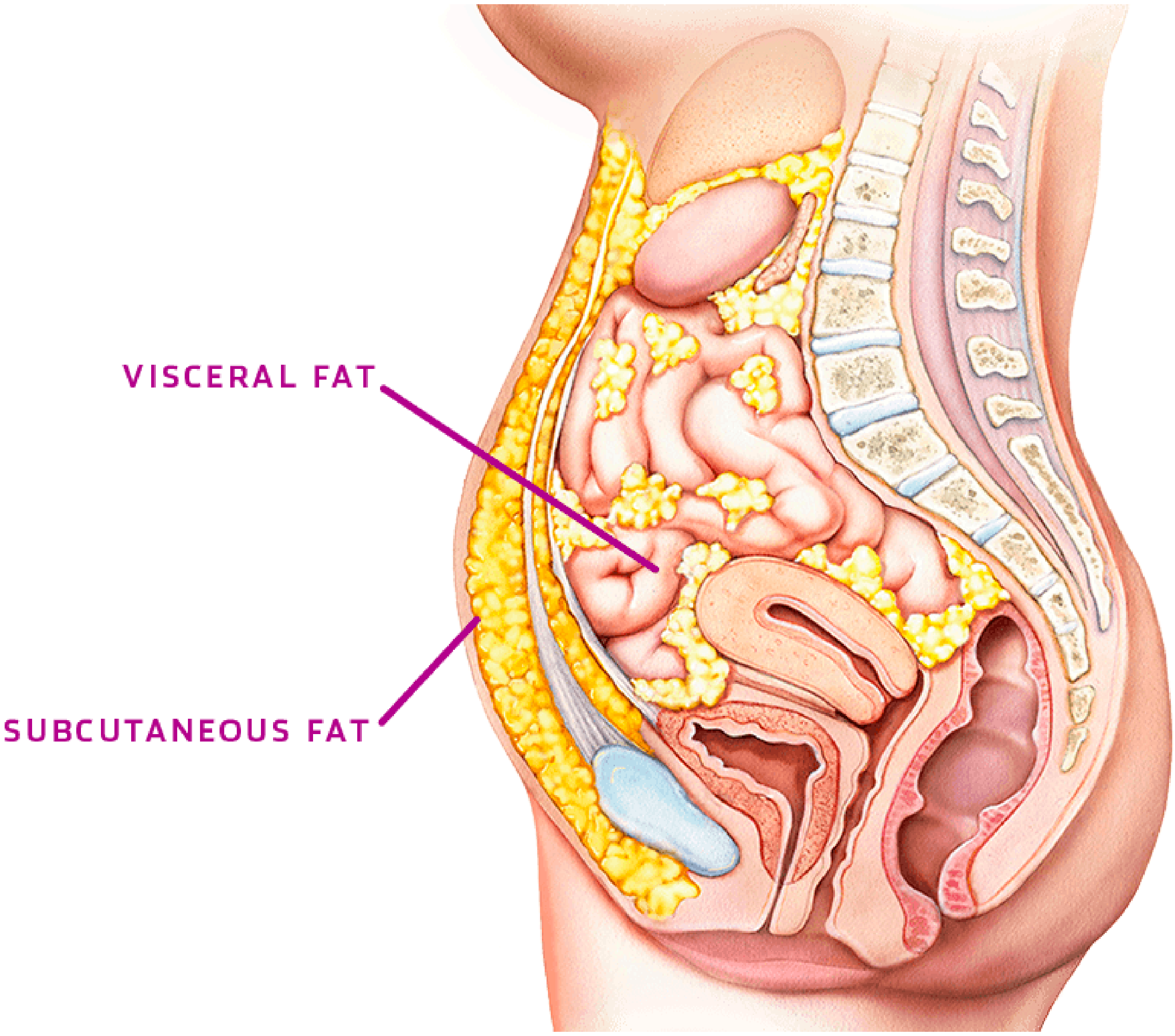

Figure 1: Representative image of subcutaneous versus visceral fat, from AMA 17.

Non-subcutaneous fat is particularly nefarious because it is a major source of inflammation,[4] capable of secreting pro-inflammatory cytokines and chemoattractant molecules that attract and reprogram immune cells[5] to an inflammatory phenotype, further exacerbating inflammation. Outside of the effect of non-subcutaneous fat on systemic inflammation, its spatial proximity to major organs can result in more direct negative effects on those organs (e.g., heart, pancreas), contributing to the development of atherosclerosis and metabolic syndrome. Metabolic syndrome, in turn, increases the risk of cancer, neurodegeneration, and other diseases.

A large study[6] conducted using UK Biobank data exemplifies a broader literature on non-subcutaneous fat and negative health consequences. It showed that those in the highest quartile of visceral adiposity index had a 20% higher risk of all-cause mortality (hazard ratio[HR]=1.200, 95% CI: 1.148-1.255), 22% higher risk of cancer mortality (HR=1.224, 95% CI: 1.150-1.303), and 46% higher risk of cardiovascular disease morality (HR=1.459, 95% CI: 1.314-1.621) compared to those in the lowest quartile. In particular, the finding that those with BMI *less* than 25 showed significantly *higher* HRs for all-cause mortality (HR=1.31, 95% CI:

1.20-1.44) for mortality indicates that VAT is dangerous *independently* from overall fat mass, as those with BMI or 25 or greater had a comparatively lower HRs for all-cause mortality (HR=1.16, 95% CI:1.10, 1.23).

Unfortunately, we have no way of controlling how our total body fat distributes between subcutaneous fat and non-subcutaneous fat, as capacities for subcutaneous fat storage vary across individuals in a manner that appears to be determined primarily by genetics. Eventually, with enough total fat accumulation, everyone will experience an accumulation of fat outside of their subcutaneous stores, but the threshold at which this will occur cannot be pinpointed, as each individual is different. I often describe this phenomenon using the analogy of a bathtub. Everyone has a different size bathtub (capacity for subcutaneous, or “safe,” fat storage). Water (fat) in the bath (subcutaneous stores) is okay, but if water continues to be added faster than it drains, it will inevitably spill over, and that spillover (accumulation of non-subcutaneous fat) is what is most damaging. However, since we have no control over the size of the tub, our best chance at avoiding this spillover is to limit the amount of water flowing in or increase the water flowing out – in other words, to reduce *overall* fat mass (resulting in an associated[7] decrease in fat outside of the subcutaneous stores).

Lean Mass

Lean mass[8] includes skeletal muscle mass, which is the tissue we typically focus on, and makes up the majority of lean mass. One study[9] estimated that on average that 38.4% of men’s total body mass and 30.6% of women’s total body mass is made up of skeletal muscle. Take two examples of fifty-year-old individuals in the 50th percentile or lower by fat mass for their sex: for a male with 15% fat mass, that would mean 45.2% of his lean mass is muscle, while for a female with 25% fat mass, that would mean 40.8% of her lean mass is muscle. However, lean mass also includes the mass of other non-fat and non-bone body parts, including internal organs and skin. Increased muscle mass (and the strength that generally accompanies it) prevents frailty as we age, which both improves quality of life and decreases fall risk in old age. Because falls and associated fractures dramatically increase mortality risk with increasing age, fall *prevention* is key to successful aging. In addition, muscle mass has positive effects on glucose tolerance because muscle cells help shunt glucose from the bloodstream, improving whole-body metabolism.

An abundance of data suggests that muscle mass is strongly and inversely associated with mortality. For example, one prospective cohort study[10] identified that in men and women aged 70-79, greater loss of thigh muscle (after correcting for overall weight change, demographics, and chronic disease) over a five-year period was associated with a higher mortality risk over the subsequent 12 years (male HR: 1.21, 95% CI: 1.08-1.35; female HR: 1.18, 95% CI: 1.01-1.37). Additionally, one meta-analysis[11] reported that those with greater muscle strength, measured by both grip strength[12] and knee extension strength test,[13] had a lower risk of ACM compared to those with lower muscle strength. High grip strength conferred a 31% risk reduction for ACM (HR=0.69, 95% CI: 0.64-0.74), while knee extension strength conferred a 14% risk reduction for ACM (HR=0.86, 95% CI: 0.80-0.93).

Changes in body composition with age

Thus, while fat mass has the ability to become a potent mediator of inflammation, atherosclerosis, and insulin resistance, lean mass – at least in the form of skeletal muscle – works in much the opposite way: it improves the body’s ability to handle blood glucose, which in turn positively impacts multiple aspects of health (not to mention the additional benefits in preventing frailty and bone deterioration). Thus, though two people may be equivalent in BMI, differences in body composition may mean that they differ radically in their underlying health. Likewise, having the same BMI at age 60 as you had at age 30 cannot be interpreted as evidence of equivalent metabolic health between the two ages.

Body composition changes naturally with age, which is why it is so critical to monitor these metrics over time. From birth to our early/mid-twenties, we rapidly gain muscle mass, but after about age 40, muscle mass begins to decline, a process which accelerates with further advances in age (Fat-Free Mass (FFM) in **Figure 2**). Building up a reserve of muscle early and maintaining it into older age can help buffer some of the negative effects of this age-related muscle decline. Fat mass also has a distinct pattern of change throughout life, but tends to *increase* throughout life (Fat Mass (FM) in **Figure 2**). (Note: the small decline apparent among the oldest ages likely reflects the loss of fat that accompanies advanced diseases such as dementia or cancer.)

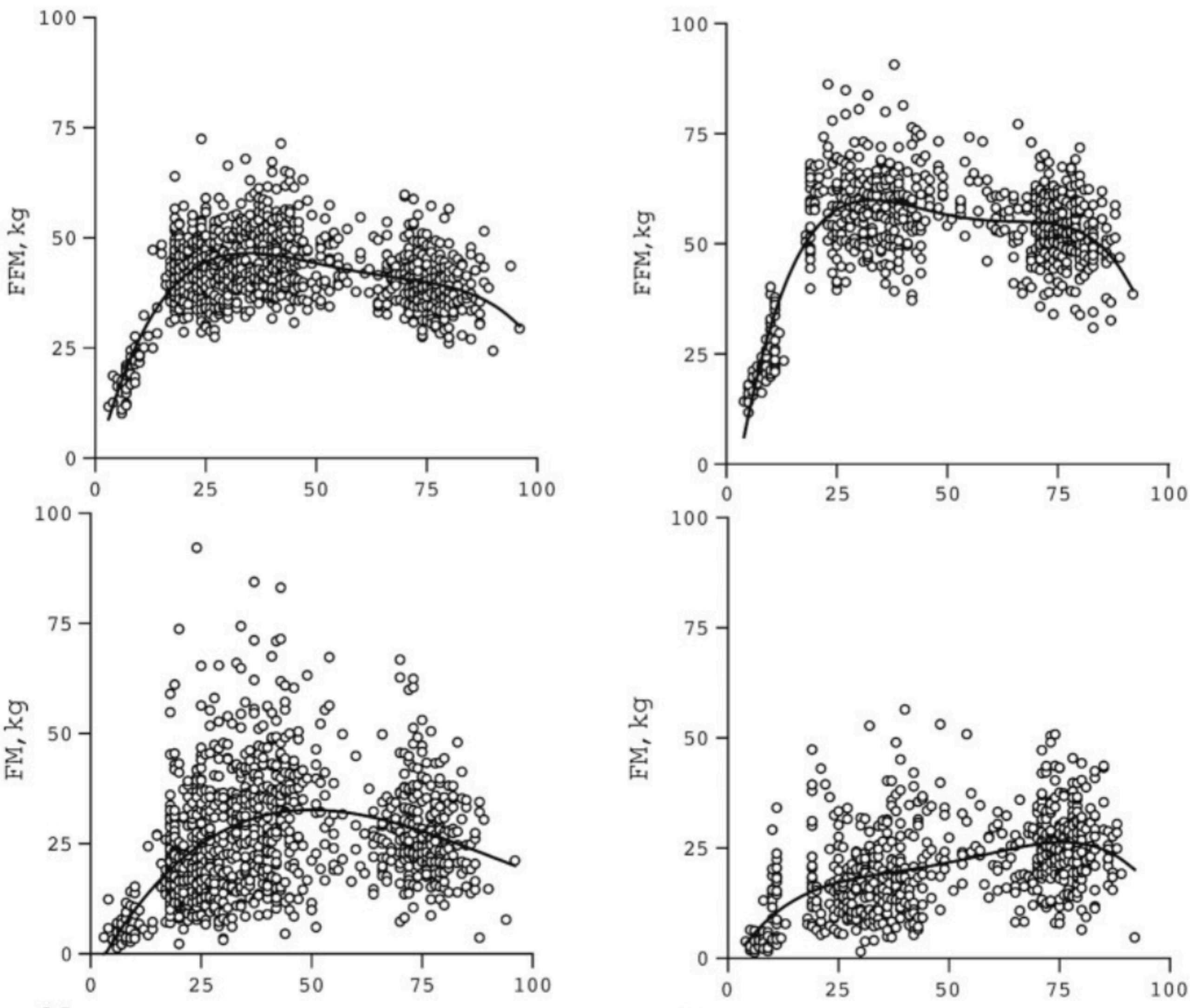

Figure 2: Fat-free mass (FFM) and Fat Mass (FM) as a function of age, plotted from data from 1182 females (left) and 818 males (right), from Westerterp et al., 2021.[14]

So given the associations between body composition and health, as well as the changes in fat and lean mass as we age, how can we assess our own body composition and keep an eye on how it changes over time?

Determining Body Composition

A number of methods exist for estimating body composition, ranging from imprecise to extremely accurate. Here, we will discuss many of them in turn, highlighting advantages and disadvantages of each.

Anthropometric Estimates

Anthropometric measurements involve measurements of body proportions. This class of metrics includes BMI and body weight, though as we've established, these are useless as measures of body composition. However, two alternative anthropometric measurements do facilitate some (albeit limited) estimation of body composition: waist circumference and bioelectrical impedance analysis.

Waist circumference has been shown to correlate fairly well[15] with visceral fat deposition. However, because waist circumference is a measure of both subcutaneous *and* visceral fat, it does not specifically indicate the amount of visceral fat within a person, which, as previously detailed, is the measure of greatest interest.

Bioelectrical impedance analysis[16] (BIA) is a method of determining body composition involving passage of a weak electric current through the body to measure resistance and reactance. Because water is reactive, and muscle tissue contains more water than fat tissue does, this approach can give an estimate of fat mass and muscle mass. BIA is the technique employed in many at-home scales (typically featuring small metal foot pads), which provide measurements of fat mass, bone density, muscle mass, and water content in addition to the body weight measure provided by more traditional scales. This method is superior to any of the aforementioned metrics in providing information on body composition because it offers an estimate of the relative amounts of fat and muscle mass. Further, because BIA measurements provide differentiated measurements of visceral fat and subcutaneous fat, it is a more specific measure of body composition than waist circumference. However, BIA are highly variable and highly contextually dependent. For example, BIA readouts depend significantly on water content, and as such, dehydration can increase resistance, resulting in underestimated muscle mass and overestimated fat mass. Additionally, exercise also reduces resistance, and measuring body composition immediately following exercise can overestimate muscle mass and underestimate fat mass. So if you’re going to use this method, be as consistent as possible about the time of day and hydration status, and even then it is probably more useful as a tool for guiding change rather than absolute levels.

The (Impractical) Gold Standards: MRI and CT

Magnetic resonance imaging[17] (MRI) is an imaging technique that uses a large magnet (on the order of 1-7 tesla) and radio waves to align and deflect protons in the body. The process of deflecting these protons and measuring the speed with which they return to the aligned position provides information about the tissue composition in any given bodily region and provides a wealth of detail in extremely high resolution. Cost aside, MRI would be by far the best method to measure body composition, providing excellent detail in a very safe and non-invasive setting. However, the whole-body MRI services that offer body composition profiles take more than an hour and cost more than $2,000 at many commercial MRI locations in the United States – creating a substantial barrier to the widespread use of this method.

A computed tomography[18] (CT) scan is also an excellent method to differentiate and assess elements of body composition and works by combining a series of X-rays taken at various angles around the body. However, the number of X-rays needed to assemble a full-body CT image results in radiation exposures that amount to *at least* (but often much more than) 20 millisievert[19] (mSv), which is 40% of the annual limit for occupational radiation exposure in the United States (50 mSv) and the entire annual limit for radiation workers in Europe. For reference, a hand or foot X-ray, the type one might receive in the emergency room or at an orthopedic clinic, is estimated at around 0.001 mSv per scan. CTs are amazing tools for medically necessary indications, but there is no reason to expose anyone to that level of radiation to learn about body composition, since fortunately, a safer and still informative option is available – namely dual-energy X-ray absorptiometry[20] (DEXA).

The Best Balance of Costs and Benefits: DEXA

Like CT scans, DEXA scans use X-rays to measure how energy passes through your body, which varies by tissue type and thus can be used as a means of differentiating between tissues. DEXA scanners project linear beams of two different energies – a high-energy beam and low-energy beam – through the body, and absorbance of energy in any given area (as detected by a reduction in electrons from the beams after passing through the body) indicates the local tissue composition.

Despite using X-rays, the radiation doses associated with DEXA scans are far below those associated with CT scans, amounting to only around 0.003 mSv[21] for a whole-body scan (for comparison a flight from Los Angeles to New York exposes you to ~0.035 mSv, while a flight from Los Angeles to Tokyo exposes you to ~0.054 mSv), and at a price tag of around $100-300 depending on the location. Though the resolution is lower than the resolution achieved using an MRI or a full-body CT scan, data from DEXA scans can be used to determine bone mineral density, as well as fat mass and lean tissue. This information also allows the calculation of four additional metrics on body composition: (i) fat-free mass index, (ii) appendicular lean mass index, (iii) total body fat, and (iv) visceral adipose tissue, each of which is discussed in greater detail below. Thus, DEXA is regarded as a safe and cost-effective means of obtaining meaningful, detailed information about body composition.

DEXA-Derived Measures of Body Composition

Strictly speaking, a DEXA scan can measure three things: bone, fat, and “other.” In addition to muscle, this last category encompasses organs, water, and any other non-fat, non-bone mass, though it’s often all referred to as “lean mass.” Thus, the test cannot directly differentiate between subcutaneous fat and VAT or between skeletal muscle and organ mass, etc.

However, in addition to providing sum totals of how much bone mass, fat mass, and lean mass are present, a DEXA scan also generates a *two-dimensional image* of how these categories of mass are *distributed* throughout the body, which allows us to infer additional detail about each category, giving rise to other useful metrics such as appendicular lean mass and VAT. These metrics, along with the more direct measurements, can then be compared to reference ranges for a given population, which vary across age groups and between sexes.

A Brief Word on Bone

Though the focus of this review is on metrics related to fat mass and lean mass, bone mineral density – the third category detected by a DEXA scan – deserves brief mention. Bone mineral density is a measure of bone mineral content in grams normalized to area, which is reported as a z-score[22] (a score derived from the population distribution, calculated as an individual’s mean bone mineral content score minus the population mean divided by the population standard deviation, so a z-score of +1.0 means a person is one standard deviation above the mean while a z-score of -0.5 means they are half a standard deviation below the mean). Bone mineral density declines with age, potentially leading to conditions such as osteopenia and osteoporosis which increase risk of fractures. Among the elderly, fractures – particularly of the hip and pelvis – result in a massive increase in mortality[23] risk, so preserving bone density is a matter of utmost importance, and this metric certainly should not be ignored in reviewing results of a DEXA scan. For further information on bone health, including what constitutes healthy bone density and how to improve or maintain bone density as we age, check out AMA 37.

Fat Free Mass Index

Of the two DEXA-derived metrics related to lean mass, fat free mass index (FFMI) is the more inclusive of several types of non-fat tissue. FFMI is a measure of *all* mass that isn't fat – including muscle mass as well as the mass of internal organs, connective tissue, skin, and bone – relative to height. However, muscle mass accounts for a large proportion of this measurement, so the goal for FFMI is to be as high as possible – preferably at or above the 75th percentile and never below the 25th percentile (see **Figure 3** for a blank copy of the FFMI nomogram).

FFMI is often (but not always) provided on a DEXA report. If it is not provided, it can be calculated using the following formula:

[total lean mass in kg] ÷ [height in meters, squared] + (6.1 x [1.8 – height in meters])

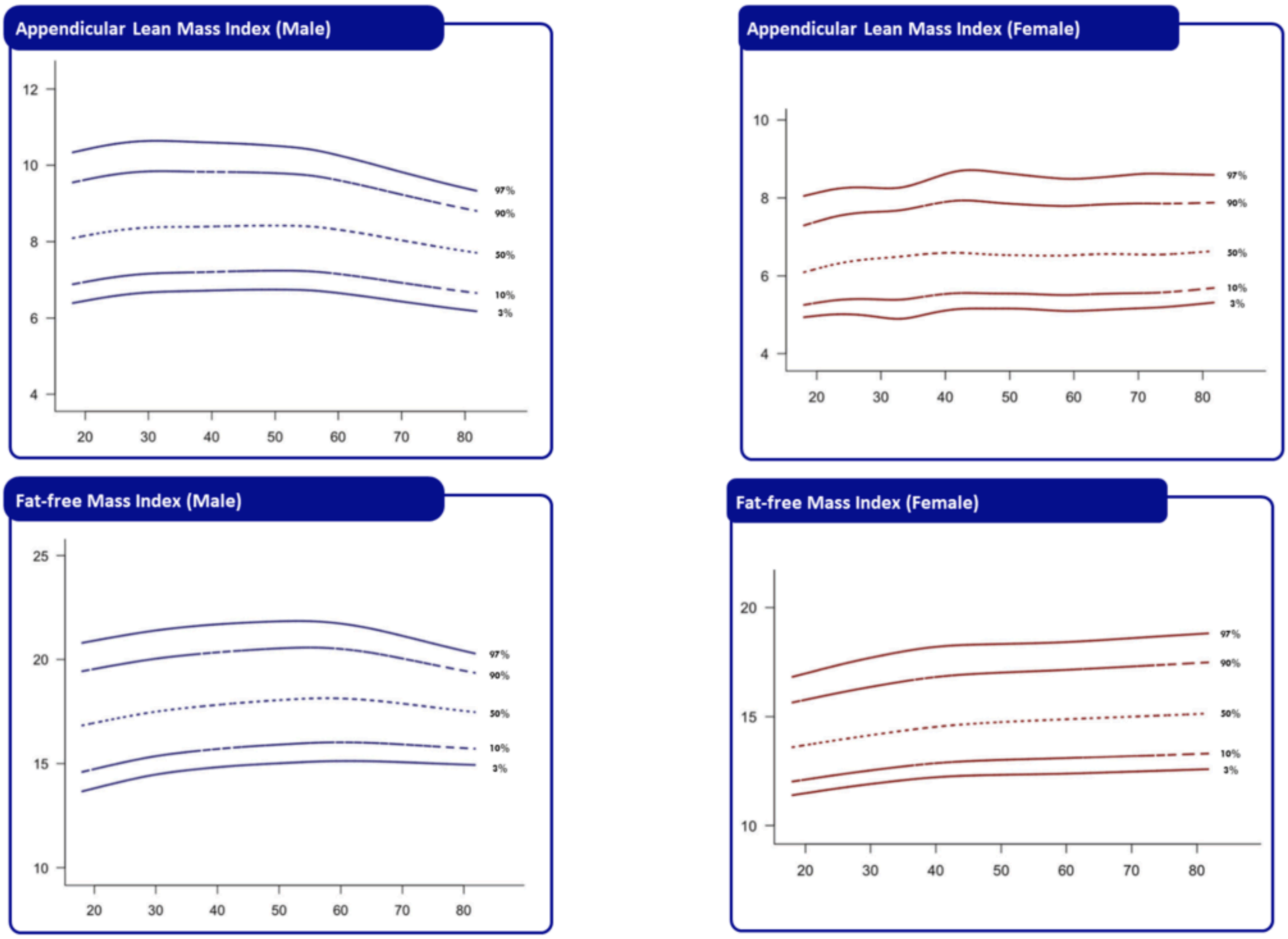

Figure 3: Blank copy of appendicular lean mass index (ALMI; top) and fat free mass index (FFMI; bottom) nomograms, with male nomograms on left and female nomograms at right by age.

Appendicular Lean Mass Index

The second DEXA-derived metric related to lean mass is appendicular lean mass index (ALMI), a measure of the amount of mass that is not fat *in the arms and legs* relative to height. Like FFMI, this measure includes muscle mass as well as mass from connective tissue, skin, and bone. However, unlike FFMI, ALMI does *not* include mass from internal organs, as these organs are not located within the arms and legs. Thus, though ALMI is typically well correlated with FFMI, ALMI is regarded as a purer estimation of skeletal muscle mass. In the case of discordance between the two measures, ALMI is therefore the preferred metric for informing lifestyle interventions, given that it provides a more accurate estimation of lean mass in the form of skeletal muscle, the form that is of greatest interest for longevity and healthspan.

The goal for ALMI is to be as high as possible. Though it's possible to build muscle mass in older age (as exemplified by a 93-year-old rower we covered recently), muscle mass declines with age and generally becomes harder to put on, so building up the "reserve" of muscle mass ahead of time is important. The more muscle there is to lose, the longer you can lose it while still remaining strong enough to be independent and proficient in the activities of daily living.

ALMI is often (but not always) provided on a DEXA report. It may also be called "Relative Skeletal Mass Index" or "RSMI" on a DEXA report. If it is not provided, it can be calculated using the following formula:

[lean mass in arms in kg + lean mass in legs in kg] ÷ [height in meters, squared]

Genetics play a role in muscle building, and as a result, not everyone will be capable of reaching the 75th percentile for ALMI. Still, a reasonable goal regardless of genetic background is to be above the 50th percentile or higher and never to dip below the 25th percentile (see **Figure 3** for a blank copy of the ALMI nomogram).

Total Body Fat

Besides lean mass and bone density, DEXA scans also provide a measurement of an individual's fat mass. Total body fat measures can be produced with one of two calculations: (i) the total amount of fat divided by the total mass of the individual or (ii) the total amount of fat divided by the squared height of the individual. In either case, the result is provided as a percent.

Although the *distribution* of fat (i.e., between visceral and subcutaneous fat depots) is of greater importance for metabolic health than total fat mass, reducing total fat mass is not without benefits. As explained previously, decreasing total fat is the only strategy by which one can attempt to reduce visceral fat, and furthermore, reducing high total body fat may be beneficial for orthopedic health. Excess fat mass increases the weight load that must be borne by joints, and therefore, overweight and obesity are linked to higher rates of orthopedic injuries,[24] osteoarthritis,[25] and joint replacements.[26] (Note that skeletal muscle mass should not result in similar orthopedic problems, as muscle can stabilize the joints – assuming movement is performed with correct form – and the process of building and using skeletal muscle serves as a stimulus for strengthening bones and joints.)

Generally speaking, the goal for total body fat is to be as low as possible while maintaining the body's basic needs, a level which varies by sex. Men can tolerate as little as 2-3% body fat, while women, particularly those who are premenopausal, typically require at least 10% body fat (see **Figure 4** for a blank copy of the total body fat nomogram).

Visceral Adipose Tissue

Though total body fat and visceral fat are related, they can occasionally be discordant – for instance, one can be skinny and possess large amounts of VAT or overweight with very little VAT – and as we've seen, visceral adipose tissue (VAT) is the more critical of the two metrics when it comes to metabolic health and risk of chronic disease. VAT is estimated differently by different DEXA scanner models, but as an example, reports from Hologic DEXA scanners use an estimate[27] of VAT that tabulates it as the fat mass that lies within the L4-L5 region of the abdomen.

Everyone should aim to reduce VAT to as low a level as possible, as even a small amount of VAT can have substantial negative consequences for health. Blank nomograms for VAT are presented in Figure 4; at a maximum, the goal for VAT should be to remain below the 10th percentile for one's age and sex. However, because VAT cannot be specifically targeted, reducing VAT typically requires reducing total body fat (such as through calorie restriction[28] and exercise[29]), and indeed, losses in total body fat have been shown to correlate strongly with losses in VAT.[7]

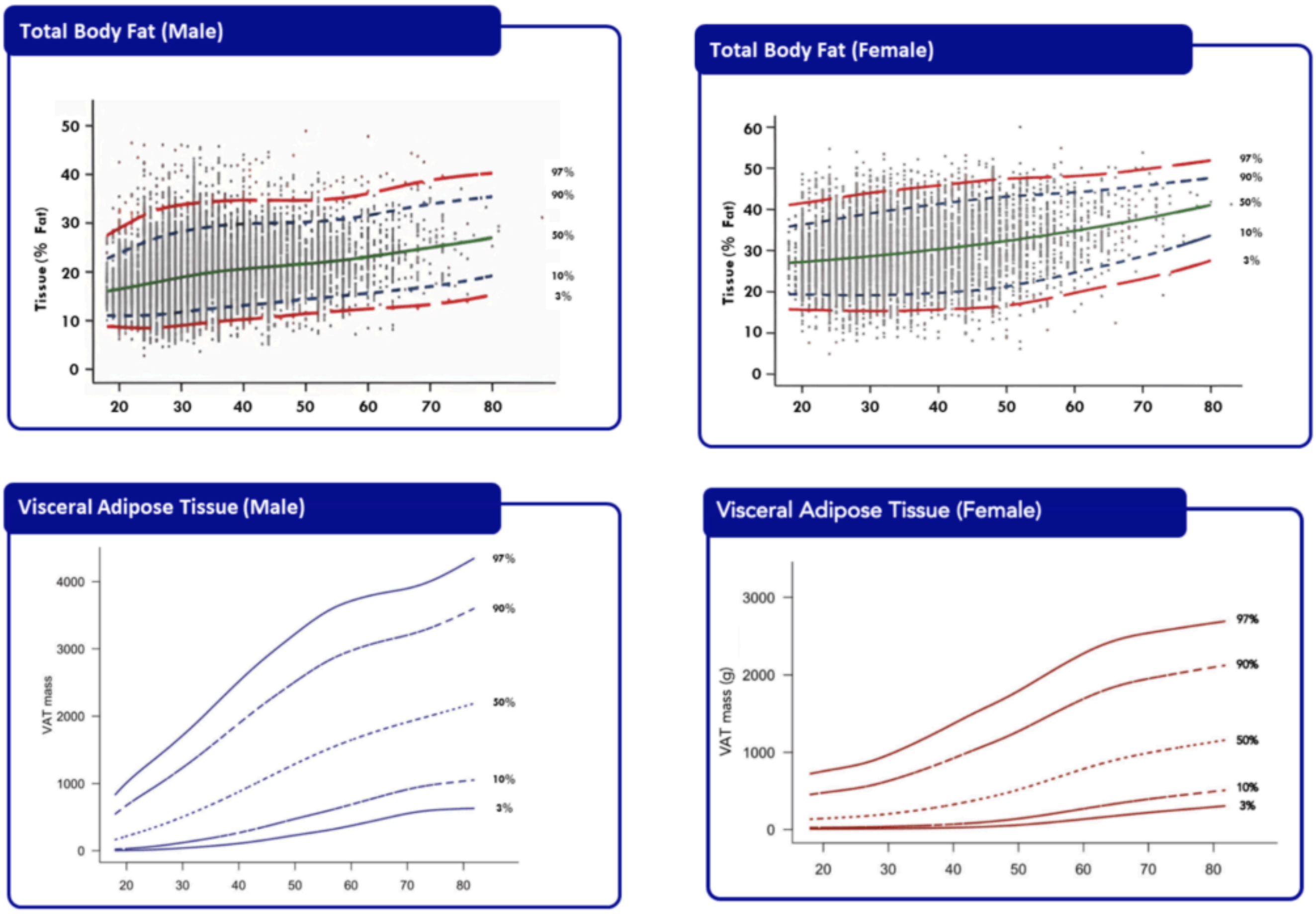

Figure 4: Blank copy of total body fat (top) and visceral adipose tissue (VAT; bottom) nomograms, with male nomograms on left and female nomograms at right by age.

DEXA Limitations

Though DEXA is an invaluable tool for understanding body composition, certain limitations are worth noting.

The most fundamental limitation concerns how data derived from a DEXA scan is reported. Information is distilled from the two-dimensional scan down to specific numbers (i.e., fat mass, lean mass, and bone mineral density) to generate the the five total scores described above. Yet through this distillation, important information on the *distribution* of fat/lean mass throughout the body is lost (an issue addressed previously in a weekly newsletter on DEXA and artificial intelligence). The distribution of VAT would be of particular interest, as it would offer clues regarding the organs at highest risk (i.e., pericardial VAT increases risk of heart failure,[30] while intrapancreatic VAT increases risk of insulin resistance[31]) and might thus inform future screenings or interventions (e.g., dietary suggestions specifically supporting cardiovascular health, rather than purely calorie restriction). Of note, this issue of simplifying multi-dimensional images into a handful of numbers is not unique to DEXA and applies to body composition reports provided by any imaging modality.

Other limitations are more specific to DEXA. First, because DEXA scans do not differentiate separate types of lean mass (water versus organs versus muscle), hydration status can significantly impact scores on the lean mass metrics. For example, if an individual were to get a scan, chug a few glasses of water, and then immediately have another scan, their lean mass would potentially change by several pounds. Dehydration can likewise lead to *underestimation* of lean mass, so for instance, because exercise is often moderately dehydrating, exercise before a DEXA scan might result in underestimation of lean mass.

Second, though DEXA scans report an *estimate* of VAT which may be valuable in gaining a broad picture of an individual's visceral fat, this estimate is fairly inaccurate relative to the measures of VAT provided by MRI (the "gold standard"). In one study[32] comparing VAT assessment by DEXA versus MRI among people undergoing exercise intervention, DEXA-derived VAT metrics correlated fairly well with MRI-derived VAT metrics cross-sectionally (r=0.9 at baseline and r=0.67 at 3 and 12 months), but DEXA scans overestimated baseline VAT by 13% and underestimated *longitudinal changes* in VAT by 33% at 3 months and 47% at 12 months. This study reported that the minimally clinical important difference detectable on an MRI is 75 cm^3 for MRI-VAT volume and 15 cm^2 for MRI-VAT cross-sectional area, so given the poor agreement between MRI and DEXA in longitudinal changes of VAT, this implies that the ability of DEXA to detect *small changes* in VAT would be poor. With that said, getting an estimation (albeit an imprecise one) of VAT does allow a general understanding of whether that metric is appropriate or too high relative to the population, which can help direct interventions.

However, despite the limitations of DEXA scans, they are difficult to beat for their cost-benefit trade-off (money and radiation versus information gained). The estimates of muscle and fat mass provided by DEXA scan reports allow us to make targeted changes in lifestyle practices to optimize body composition in a way that would not be possible using anthropometric estimates.

Which brings us to the final two considerations: how to get a DEXA scan, and what to do when you have the results.

How to get DEXA scan

There are several general guidelines to follow when preparing for a DEXA scan:

1. Get a DEXA scan first thing in the morning. It is important not to eat or drink before a scan because food and water can impact the results. Drinking water (as well as eating food) right before a scan will result in a falsely inflated lean mass value. Also, use the restroom before getting a scan to avoid urine skewing lean mass results.
2. Don't exercise before getting a DEXA scan. Exercise can temporarily dehydrate you and lead to inaccurately low lean mass readings.

3. If you are asked to provide your height (rather than it being measured directly during your DEXA scan), be honest about it. People tend to slightly overestimate their heights, but doing so in this case can result in falsely decreased lean mass measurements, as lean mass measurements are normalized to height. A greater denominator (i.e., height) leads to a reduced overall estimate.
4. Don't get a DEXA scan more than every nine to twelve months. Having enough time between scans allows any interventions to make a sufficient difference in body composition to reflect on scan results. With shorter between-scan intervals, differences in measurements are more likely to be attributable to scan-to-scan variability or hydration status. Because studies[33] have shown that the coefficient of variation for fat mass on DEXA scans on the same people separated by only two weeks is 1.6%, serial scans must be far enough apart to capture changes in body fat that exceed that magnitude in order to be certain that real changes are being captured, rather than scan-to-scan variance.
5. Because scanner-to-scanner variability can be high, always aim to get scans on the same scanner. The parameters and calibration of different machines can result in completely different results, so comparing scans from two different facilities is like comparing apples and oranges.

Regarding *where* to get a scan, a company we often recommend to our patients (largely because it is a national company with facilities all around the country) is Dexafit.[34] Other nation-wide companies providing DEXA scans include Fitnescity,[35] and other DEXA scan locations near you can be found using websites such as dexascan.com.[36] Whatever the facility, it's important to ensure that they regularly (read: *daily*) calibrate their DEXA machine to ensure accurate readings over time and that they get the machine serviced when readings are no longer consistent.

Side note: If you're looking to get a DEXA scan to determine bone mineral density, it's helpful to ask how often this type of scan is performed at that particular location. Because positioning on the machine can impact the readings for this metric, it's highly recommended to find a facility with a technician who is trained on proper positioning and performs bone mineral density DEXA scans regularly.

While many DEXA scanning locations provide reports that include all of the parameters just detailed, not every place will provide those exact metrics. However, all will provide the data that you need to calculate those metrics yourself, using the formulas above.

Once you have your body composition metrics, you can compare your measurements to target ranges by sex and age to know where exactly you stand, which in turn allows you to determine which interventions, if any, should be made.

Improving *your* body composition

Optimal interventions for improving body composition naturally depend on which areas are of greatest concern at baseline, and the two criteria which matter most in this respect are (i) nourishment (indicated by fat mass), and (ii) muscle. For instance, for one who has relatively little fat mass but is very low on muscle, calorie restriction is not nearly as important as ensuring adequate protein intake and strength training.

Given these two criteria, ideal interventions can be determined by placing yourself into one of four categories within a two-by-two matrix: (i) Under Muscled and Overnourished; (ii) Adequately Muscled and Overnourished; (iii) Under Muscled and Adequately Nourished; or (iv) Adequately Muscled and Adequately Nourished (**Figure 5**). Whichever category you fall into based on your results determines the necessary interventions. Case studies of each category and the suggested interventions are discussed in some detail in [AMA 40](), but are briefly detailed below (at the risk of oversimplifying for the sake of brevity, obviously there is more nuance to this):

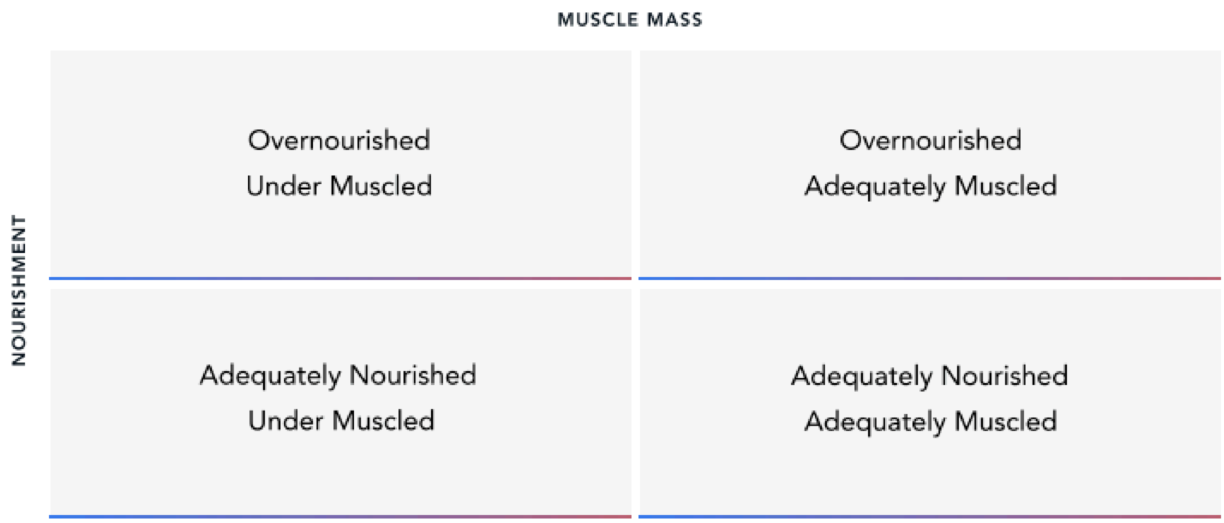

Figure 5: Two-by-two grid with muscle mass status at top and nourishment status along the side. After receiving DEXA measurements, each person can be classified within one of the four categories, which directs the subsequent interventions.

Category 1: **Under Muscled and Overnourished**

Restrict calories without compromising the amount of protein you're eating, which is important in promoting muscle growth.

Focus exercises on lifting weights/resistance training to build muscle, but increase cardiovascular exercise, as well.

Category 2: **Adequately Muscled and Overnourished**

Restrict total calories, particularly if high VAT is a concern. If VAT is not high, choosing to restrict calories is primarily for aesthetic and/or orthopedic injury purposes. If you choose to restrict calories for weight loss, it is okay to be at the lower end of protein intake, but don't compromise protein so much that it becomes difficult to build or maintain lean mass.

Continue with weight lifting/resistance training but increase cardiovascular exercise.

Category 3: **Under Muscled and Adequately Nourished**

Focus primarily on increasing protein intake. If you happen to be undernourished, increase overall calorie intake in addition to protein intake. If you're adequately nourished, increase protein while keeping total calorie intake roughly constant.

Increase the amount of weight lifting/resistance training you're doing, and if you're doing a lot of cardiovascular exercise, consider reducing it.

Category 4: **Adequately Muscled and Adequately Nourished**

Keep at it. Focus on going deeper into your exercise and nutrition goals and fine tuning training and nutrition.

The bottom line

Body composition is a vital – yet often ignored – indicator of health and predictor of chronic disease and mortality. A variety of options for assessing and tracking body composition, ranging from relatively crude anthropometric measurements to highly accurate MRIs, with DEXA offering a middle ground that provides the best balance of cost and information gained.

But simply *having* information about one's body composition is only the first step. For these data points to be useful in promoting a longer, healthier life, we must *act* on the information through diet, exercise, or other interventions as a means of *improving* body composition and overall health.

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